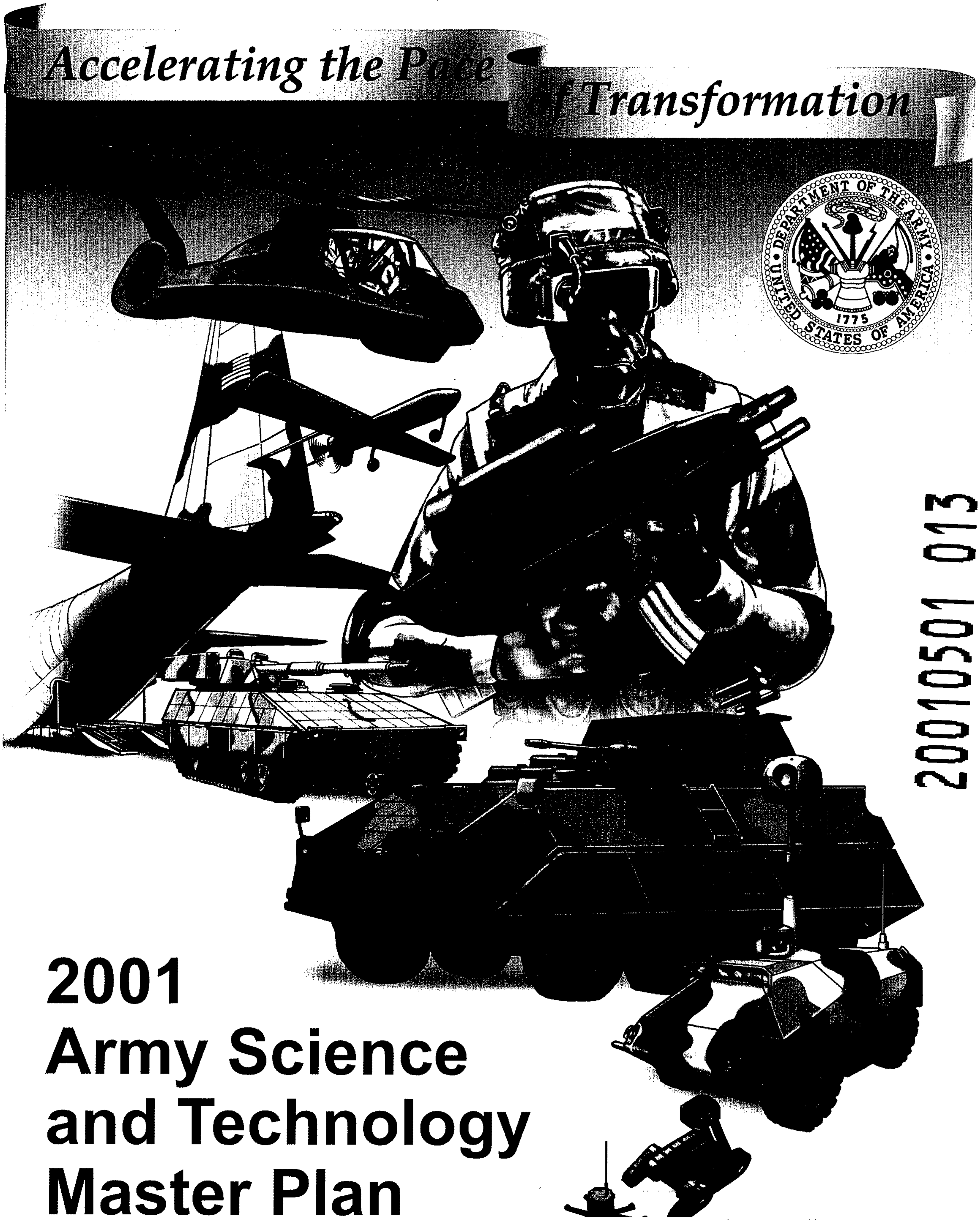

2001 Army Science and Technology Master Plan

VOLUME I

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DEPARTMENT OF THE ARMY
WASHINGTON DC 20310

In this time of relative peace and prosperity, between the industrial age of the Cold War era and the information age of the new millennium, we have a "window" of opportunity to transform The Army to meet the challenges of the 21st Century. The science and technology program described in this Army Science and Technology Master Plan captures the intent of The Army Vision with investments that will accelerate The Army's Transformation. Our investments today will provide the fundamental science and technology for the systems we need to become strategically responsive and dominant across the entire spectrum of military operations.

While we will continue to maintain the overmatching combat power of our Legacy Forces, our emphasis is on developing and fielding a Transformed Army—an Objective Force this decade. This will be a force that is dominant in all missions ranging from peacetime engagement to Major Theater War. More capable than today's force, the Objective Force will have greater strategic responsiveness, increased lethality, greater survivability, and reduced sustainment costs.

The Army has focused the intellectual and financial resources necessary to establish irreversible momentum for Transformation. With our emphasis to have technological solutions in 2003, we have achieved considerable success in acquisition reform continuously evaluating the way we leverage and exploit technology opportunities in other Agencies and private industry. The Future Combat Systems program exemplifies the technical collaboration and synergy that we need as we develop the Objective Force.

Through all this technological change, the one constant is our Soldiers who remain the centerpiece of our formations. They help provide the continuity, leadership and expertise needed to carry us through the 21st Century. To support them, The Army's scientists and engineers are committed to providing our Soldiers with the best technologies available to achieve The Army Vision.

ERIC K. SHINSEKI
General, United States Army
Chief of Staff

Gregory R. Dahlberg
Acting Secretary of the Army

AQU01-07-1380

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
ACQUISITION LOGISTICS AND TECHNOLOGY
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WASHINGTON DC 20310-0103

REPLY TO
ATTENTION OF

The Army's Science and Technology (S&T) program is the "engine of change" that seeks to accelerate the Army's Transformation into a more strategically responsive force that is dominant across the full spectrum of military operations. The Army Science and Technology Master Plan (ASTMP) is the capstone planning document for Army S&T. It is the essential link between the goals stated in the Army's Transformation Campaign Plan (TCP) and the program objectives indicated in the Army's Modernization Plan (AMP).

The ASTMP also provides guidance and direction to the Army S&T community, serves as the Army's input into the Department of Defense S&T planning process and informs our industry partners of our strategic direction. It describes the funded S&T investments in the Future Years Defense Plan (FYDP) to provide the technology solutions that will enable the Objective Force capabilities envisioned in the TCP. These key investments are shown as Science and Technology Objectives (STOs) in both advanced technology development and applied research that are the "building blocks" of the S&T program. The STOs are our highest priority efforts and represent the focus we have achieved, in response to warfighter needs, to mature essential technologies that can be transitioned into Objective Force systems.

The Army has increased its S&T funding and exploited opportunities for partnership with other Agencies and industry to reduce technology development risks. We have a world-class network of Army Laboratories and Research and Development Engineering Centers. The scientists and engineers in these facilities are fully committed to providing our soldiers with the quality and quantity of technology options that will achieve the revolutionary changes needed for Army Transformation.

A. Michael Andrews II
Deputy Assistant Secretary
(Research and Technology)

Paul J. Hoeper
Assistant Secretary of the Army
(Acquisition, Logistics and Technology)

ARMY SCIENCE AND TECHNOLOGY MASTER PLAN 2001

January 2001

U.S. Department of the Army
Office of the Assistant Secretary of the Army for
Acquisition, Logistics and Technology

FOREWORD

The *Army Science and Technology Master Plan* (ASTMP) is developed under the direction of the Deputy Assistant Secretary for Research and Technology (DAS(R&T)). The ASTMP is the Army's "capstone" S&T document—a reference for senior leaders, scientists, and soldiers; a coordination document for the combat and materiel development communities; and an information compendium for industry, academia, and the Congress. It establishes the top-level guidance for the Army science and technology community and describes the key investments funded in the Future Years Defense Program (FYDP). The ASTMP is a multifaceted document for planning, programming, and execution, serving several functions for a diversity of customers:

- Provides strategic direction to the Army S&T community.
- Synchronizes the Army's S&T programs with the Army's *Modernization Plan* priorities and the *Transformation Plan* goals.
- Describes the S&T programs being executed by the Army's major commands.
- Promotes synergy, efficiency, and cooperation within Army S&T and requirements development efforts.
- Serves as the Army's baseline input to the defense S&T planning and documentation process.

The ASTMP is published in two volumes:

Volume I

- Chapter I: Army Science and Technology Strategy
- Chapter II: Training and Doctrine Command's Role in Science and Technology
- Chapter III: Advanced Technology Development (Technology Transition)
- Chapter IV: Applied Research (Technology Development)
- Chapter V: Basic Research (Discovery and Understanding)
- Chapter VI: Technology Transfer

Volume II (Available only on CD-ROM)

- Annex A: Science and Technology Objectives (STOs)
- Annex B: Advanced Technology Demonstrations (ATDs)
- Annex C: Advanced Concept Technology Demonstrations (ACTDs)
- Annex D: Logistics
- Annex E: Global Science and Technology Watch
- Annex F: Infrastructure
- Annex G: Manufacturing Technology (ManTech)

Both volumes conlcude with a Glossary of Abbreviations and Acronyms and a comprehensive Index.

The ASTMP is revised annually. Reader comments and suggested improvements are welcome. Please forward comments to:

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CHAPTER

I ARMY SCIENCE AND TECHNOLOGY STRATEGY

CONTENTS

A ARMY TRANSFORMATION I–1
1 Army Vision I–1
2 Transformation Strategy I–1

B SCIENCE AND TECHNOLOGY STRATEGY I–4
1 Strategy I–4
2 Path to Transformation I–4

C OBJECTIVE FORCE S&T I–6
1 Objective Force Technology Areas I–6
2 FCS Concept I–7
3 FCS Technology Areas I–8
4 FCS Program I–10
5 Objective Force Task Force I–11
6 Other S&T I–11

D S&T PLANNING AND OVERSIGHT I–11

E BUILDING BLOCKS OF THE S&T PROGRAM I–14
1 Science and Technology Objectives I–14
2 Advanced Technology Demonstrations I–14
3 Advanced Concept Technology Demonstrations I–17
4 Strategic Research Objectives I–20

F S&T PROGRAM CHARACTERISTICS I–20

G RESOURCING THE STRATEGY I–22

H SUMMARY I–23

List of Figures

I–1	Army Transformation Campaign Strategy	I–2
I–2	Objective Force for Full Spectrum of Missions	I–3
I–3	Army S&T Strategy	I–5
I–4	Objective Force Science and Technology	I–6
I–5	Desired FCS Functions	I–8
I–6	FCS Technology Areas, Parallel Developments, and Desired Characteristics	I–9
I–7	FCS Program Strategy	I–10
I–8	Hierarchy of Plans	I–12
I–9	Army Science and Technology Oversight	I–12
I–10	Army Science and Technology Planning Process	I–13
I–11	Anatomy of a STO	I–15
I–12	Science and Technology Objective Process	I–16
I–13	Army ATDMP Approval Process	I–16
I–14	ACTD Process	I–18
I–15	LOSAT ACTD Characteristics	I–19
I–16	Science and Technology Related to the Acquisition Process	I–22
I–17	Comparison of Old and New DoD 5000 Acquisition Models	I–24

List of Tables

I–1	Current Army ATDs	I–17

CHAPTER

I ARMY SCIENCE AND TECHNOLOGY STRATEGY

As technology allows, we will begin to erase the distinctions between heavy and light forces.

—The Army Vision

A ARMY TRANSFORMATION

1 Army Vision

"Soldiers On Point for the Nation . . . Persuasive in Peace, Invincible in War.

"The Army is a strategic instrument of national policy that has served our country well in peace and war for over two centuries. Soldiers enable America to fulfill its world leadership responsibilities of safeguarding our national interests, preventing global calamity, and making the world a safer place. We do this by finding peaceful solutions to the frictions between nation states, addressing the problems of human suffering, and when required, fighting and winning our Nation's wars—our nonnegotiable contract with the American people."[1]

The Army's transformation goal is to be a strategically responsive force that can deploy a combat-capable brigade anywhere in the world in 96 hours, a combat-capable division anywhere in the world in 120 hours, and five combat-capable divisions anywhere in the world in 30 days. The transformed Army will be an interoperable force designed for full-spectrum operations. It will be lethal, survivable, and sustainable while engaging in relentless combat. The transformed Army will dominate across the full spectrum of operations and have the agility and versatility required for rapid transition along the spectrum of operations—from humanitarian assistance to major theater war—without loss of momentum.

2 Transformation Strategy

The Army's transformation objective is described in the Transformation Campaign Plan (TCP), which is approved by the Secretary of the Army and the Chief of Staff, Army. That objective is to transform the Army into a "strategically responsive and dominant force at every point on the spectrum of operations." The TCP concept requires the Army to implement the Vision as fast as possible while sustaining warfighting readiness. Figure I–1 depicts the transformation path from today's force to the future Objective Force on three axes: the Legacy Force, the Interim Force, and the Objective Force.

[1] *The Army Vision,* October 1999.

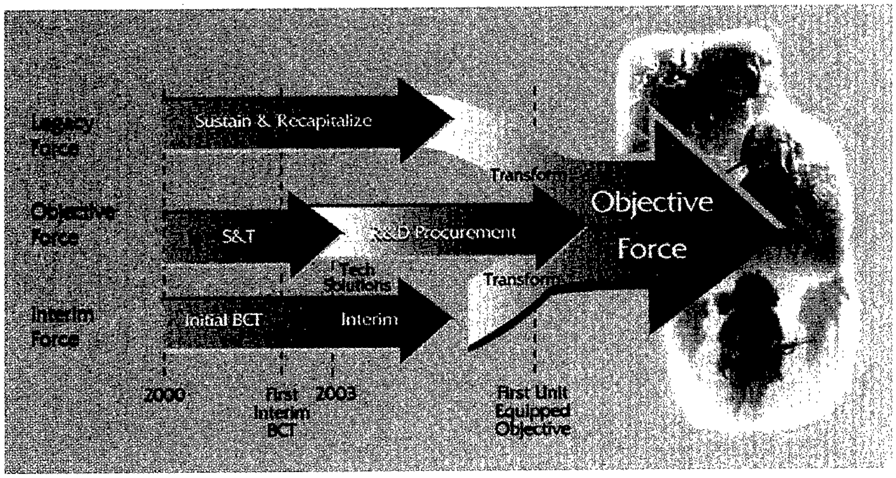


FIGURE I–1. ARMY TRANSFORMATION CAMPAIGN STRATEGY

The Legacy Force is embodied in modernized, digitized forces that evolved from the Cold War Army. These forces are the strategic hedge to support the National Command Authorities and the warfighting commanders in chief (CINCs). The Army must sustain and recapitalize this force to ensure that it is capable of fighting and winning the nation's wars throughout the period of transformation. The III Corps at Fort Hood, Texas, and the 3rd Infantry Division at Fort Stewart, Georgia, are the core of CONUS-based Legacy Forces. The Army is simultaneously beginning to field and design Interim and Objective Forces, respectively.

The Interim Force is a transition force that fills the near-term strategic capability gap that exists today. It leverages today's state-of-the-art technology, together with the Legacy Force serving as a "bridge" to the desired objective capabilities. It provides distinct advantages for deployment to small-scale contingency operations while providing more options for major theater wars. Interim Force formations provide the means to deploy a combat brigade by C–130-like transport anywhere in the world in 96 hours. These forces are equipped with a family of interim armored vehicles, lightweight artillery, and other technology while increasing tactical, operational, and strategic maneuver.

The Objective Force will be dominant across the full spectrum of operations from peacetime engagement to full combat operations in major theater wars. It will fulfill all of the force capabilities stated in the Army Vision—strategically responsive, versatile, agile, lethal, survivable, and sustainable. Figure I–2 illustrates the Objective Force operating across a full spectrum of missions. The Objective Force will be equipped with technology and organization designs to rapidly transition from humanitarian assistance to major theater of war operations without loss of momentum. The Army's S&T investments are key to achieving the Objective Force. S&T is accelerating Army transformation by increasing and focusing investments to mature and demonstrate leap-ahead technologies essential for the Objective Force.

The pace of implementing the Objective Force will be determined by technology's ability to provide expanding combat overmatch in lighter weight forces by nontraditional means. This requires the Army to move from platform-centric to network-centric warfare. Multifunctional weapon systems, integrated with multitiered command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR) into a robust system-of-systems, are the key. The Army has chosen the Future Combat Systems (FCS) as the foundation upon which the

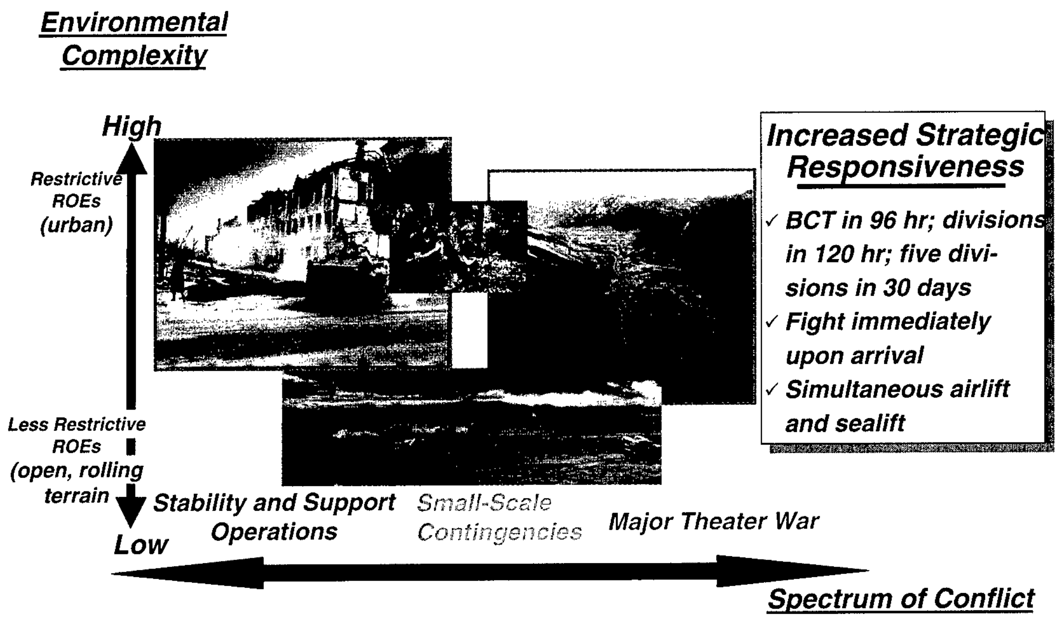


FIGURE I–2. OBJECTIVE FORCE FOR FULL SPECTRUM OF MISSIONS

Transformation will be built. In the near term, FCS is the highest priority S&T effort. The FCS represents a revolutionary approach in concept, design, and manufacturing for a new generation of land combat systems. The S&T and development acquisition goal is to build FCS within this decade.

KEY OPERATIONAL CONCEPTS FOR THE OBJECTIVE FORCE

- Strategic Responsiveness and Maneuver
- Simultaneous Engagement and Distributed Operations
- Effective Response to a Multidimensional Adversary
- Decisive Tactical Combat: Firepower, Maneuver, and Assault
- Direct Attack of Enemy Decisive Points/Centers of Gravity
- Situational Awareness and Information Superiority
- Operational Movement and Maneuver
- Tactical Maneuver/Traditional Forms of Maneuver
- Vertical Envelopment
- Mobile Strike
- Close Combat

Central to the Objective Force is the FCS. The FCS is a combat system-of-systems involving mounted and dismounted teams and manned and unmanned systems (air and ground components) that are linked by a network of C^4ISR and a network of integrated fires. The FCS and other Objective Force systems will exceed the lethality and survivability of today's mechanized forces via nontraditional approaches and will possess the strategic responsiveness associated with today's light forces. The warfighting concepts and capabilities of Objective Force systems will "blur" current distinctions and capabilities between today's heavy and light forces. This will be a strategically responsive force with unprecedented lethality and survivability— strategically and tactically "internetted" for decisive results at unmatched operational tempo.

Key capabilities of the Objective Force include:

- Deployment of combat-capable forces anywhere in the world—a brigade in 96 hours, a division in 120 hours, and five divisions in 30 days.
- All combat units capable of achieving battlefield advantage through rapid tactical movement.
- All divisions with common and internetted capabilities in C^4ISR.
- Reduced logistical demands that enable sustained operations for 30 days without resupply.

B SCIENCE AND TECHNOLOGY STRATEGY

1 Strategy

In October 1999, the Army announced a new Vision to transform itself into an Objective Force. The TCP requires the Army to implement the Vision as fast as possible. The S&T program has been reshaped and focused to speed development of technologies that will enable the Objective Force—accelerating the pace of Army Transformation.

— Accelerate the Pace of Transformation to the Objective Force —

The strategic goal is to provide technical solutions to transform the Army into a 21st century force that is dominant across the full spectrum of operations. This force must be more strategically responsive and versatile than today's force. The primary challenge is to develop and mature technologies that will eliminate current distinctions between heavy force and light force capabilities: Heavy forces must become lighter; light forces must become more lethal and mobile. This Objective Force must also be more survivable with overmatching agility while simultaneously reducing logistics demands. Most importantly, the soldier is at the center of this Objective Force.

To achieve this S&T strategy, the S&T program will:

- Develop technologies and prototype systems for the Objective Force—with the FCS as the cornerstone.
- Pursue innovation to achieve leap-ahead warfighting capabilities through technology.
- Identify and leverage the best sources of technology for the Army.
- Develop technologies to maintain essential overmatch in the current force.

The Army S&T program requires a dynamic portfolio of technology investments that is responsive to warfighter needs today and into the future. S&T seeks technological solutions that can be *demonstrated* in the near term, explores the *feasibility* of new concepts for the mid term, and seeks the *imaginable* for an uncertain far-term future.

Because of the Army's heavy reliance on the S&T community to achieve its Objective Force warfighting capabilities, enabling technologies must be adequately protected from compromise. The S&T professionals must maintain a balance between the free and open exchange necessary to stimulate solutions and the protection of technology to secure the overmatch capabilities that are sought. This is especially important as technologies are matured from applied research toward demonstration. Throughout the RDT&E process, the S&T community must work closely with the counterintelligence and security communities to ensure appropriate policies and procedures are in place to protect technologies under development.

2 Path to Transformation

The nature of S&T investments are depicted in Figure I–3. S&T must focus on providing warfighting capability in the near, mid, and far term.

The near-term priority (FY2001–2005) is on maturing and demonstrating critical technologies for the Objective Force, with major emphasis for FCS. These technologies will provide the foundation for accelerated acquisition programs to meet the timetable of the Army Vision. Key areas of investment include lethality, survivability, C^4ISR, soldier system-of-systems, semiautonomous

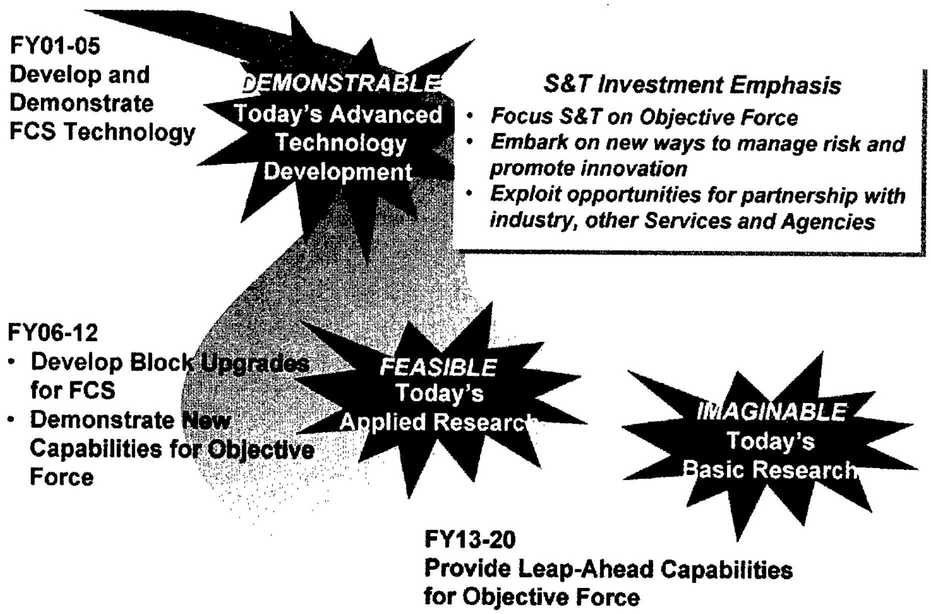


FIGURE I–3. ARMY S&T STRATEGY

air and ground robotic vehicles, human engineering, reduced logistical burden, soldier training, and medicine. Advanced technology development (6.3)[2] provides mature technologies for rapid insertion into Army acquisition programs, whether they be new systems or product improvements.

The mid-term focus (FY2005–2012) is on developing and demonstrating block upgrades for the FCS and new capabilities for the Objective Force. Investments that will provide transition products in the mid term are currently being made in the applied research (6.2) program, in areas such as lethality, survivability, C^3 on-the-move, advanced simulation, personnel technologies, and logistics demand reduction. Applied research activities are directed toward the solution of specific military problems, short of major demonstrations. This research includes the development of components, models, and new concepts through in-house and industry efforts.

In the far term (FY2013–2020), revolutionary new warfighting concepts will be enabled by current Army investments in basic research (6.1). The products of current investments in areas such as nanoscience, biomimetics, smart structures, and materials-by-design will enable significant enhancements that maintain technological overmatch in our land combat forces. Basic research activities include all efforts of scientific study and experimentation focused on understanding of fundamental phenomena with a high potential to significantly improve land warfighting capabilities. Basic research is conducted not only at Army laboratories and in-house research centers, but also in academia and industry.

This 2001 *Army S&T Master Plan* describes the corporate Army commitments to achieving the technology advances that will be required to enable the Objective Force and the Future Combat Systems.

[2] See page I-22 for a discussion of DoD budget activities.

C OBJECTIVE FORCE S&T

1 Objective Force Technology Areas

Although FCS is the main thrust of the S&T program, it represents only about one-third of all S&T funding. The majority of the Army S&T program is pursuing technologies that support the Objective Force as a whole. The major areas of investment are depicted graphically in Figure I–4. The graphic portrays the Objective Force technology areas in color bands roughly proportional to the dollar value of the investment across the FYDP. The Objective Force technology areas are described as follows:

- *Future Combat Systems*—The marquee S&T initiative enabling the Objective Force is the FCS program. The FCS will be an ensemble of fighting capabilities that meet the weight and volume constraints necessary for C–130 transportability, consisting of land combat platforms tailored to address the ground combat and mobility requirements reflected in the Army Vision. The FCS is further described on pp. I-7 through I–11.
- *C^4ISR*—Research and technology to enable comprehensive situational awareness for the Objective Force. This includes advanced sensors and sensor processing, intelligence and electronic warfare systems and techniques, militarized and special-purpose electronics, countermine technologies, and C^4 system technologies.
- *Basic Research*—Investments in the exploration of fundamental phenomena that have significant potential to enhance future land warfare capabilities, in areas such as armor materials by design, nanoscience, biomimetics, compact power, smart structures, miniature and multifunctional sensors, and soldier performance.
- *Medical*—Research and technology to protect and treat warfighters to ensure worldwide deployability, increase warfighter availability, and reduce casualties and loss of life.

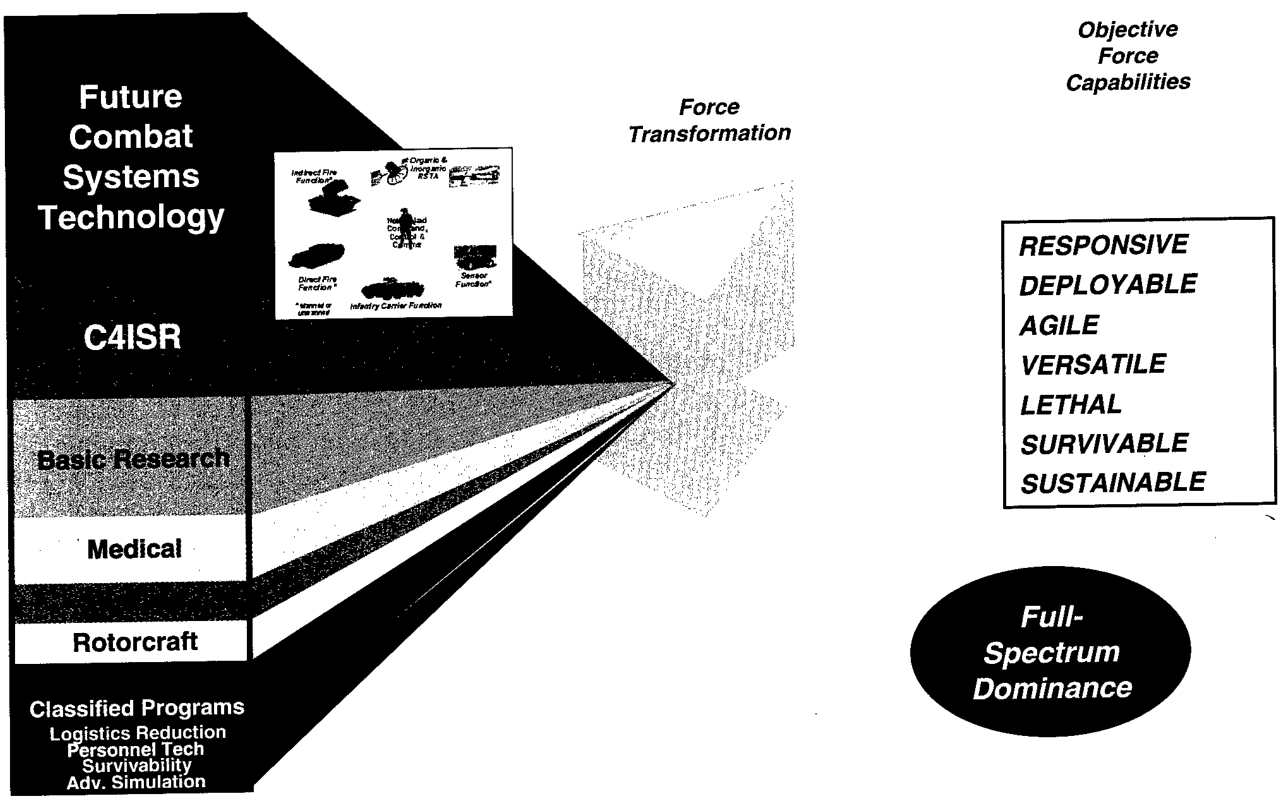


FIGURE I–4. OBJECTIVE FORCE SCIENCE AND TECHNOLOGY

- *Lethality*—Technologies to enhance the light forces, such as the Line-of-Sight Antitank (LOSAT) System and the Precision Guided Mortar Munition; and technologies to provide lethality options for the Objective Force, such as the electromagnetic gun and tactical high-energy laser.
- *Rotorcraft*—Research and technology to enhance the performance and effectiveness of future rotorcraft, including rotors and structures, propulsion and drive systems, avionics and weapons, and human–systems integration (e.g., crew station) technologies.
- *Future Warrior*—Technologies to support the future infantry soldier, including enhanced ballistic protection, clothing and equipment, dismounted warrior C^4, compact power and power management, sustenance and nutritional enhancements, soldier weapons, and warrior technology integration.
- *Logistics Reduction*—Technologies to enhance deployability and reduce logistics demand. Examples include precision roll-on/roll-off air delivery, technologies for airfields and pavements to support force projection, 21st century truck, and robotics to support resupply and reduce demand for food, fuel, and water.
- *Personnel Technologies*—Advanced training tools and methods to enhance warfighter and commander abilities and performance; advanced human engineering concepts to ensure human–system physical compatibility and cognitive engineering concepts to avoid information overload and optimize task allocation to enhance warfighting effectiveness.
- *Survivability*—Technologies that enable organizations, platforms, and soldiers to avoid detection, acquisition, hit, penetration, and kill.
- *Advanced Simulation*—Simulation tools to provide increasingly realistic environments and systems to support acquisition, requirements, and training. This includes technologies for networked simulations, embedded training, constructive simulations, virtual environments, and range systems for live use.

2 FCS Concept

Developing the Future Combat Systems is the Army S&T community's unconditional highest priority. The FCS represents the central materiel solution to achieving Objective Force capabilities. The intent is to develop and field a generation of rapidly deployable combat systems that will blur current distinctions between heavy and light forces. It will solve the challenges of making heavy forces lighter, making lighter forces more lethal, and reducing logistics demands.

The FCS is not a single system or platform. Rather, it is a system-of-systems that collectively exceed the capability of any of its components. The Army is not developing "a" tank or "an" artillery system or "an" infantry carrier. Instead, the Army is developing new concepts and designs to challenge these traditional platform-centric approaches. Achieving this goal will enable a true paradigm shift—as significant perhaps as developing the machine gun, tank, and helicopter.

The FCS systems approach envisions a grouping of capabilities into at least five major functional areas (Figure I–5): direct fire, indirect fire, infantry assault, intelligence and reconnaissance, and (5) networked connectivity with overmatching synergy of functions. The Army is simultaneously developing new battle concepts, technologies, and novel system designs to achieve the full warfighting potential envisioned in the FCS system-of-systems approach.

The primary design characteristics of the FCS include networked command and control on the move, beyond-line-of-sight "direct fires," advanced long-range precision indirect fires, standoff sensors, and robotics. In addition to the technical challenges within these functional areas, there is a total system design constraint for weight—approximately 20 tons maximum per vehicle—and for volume—that of the current C–130. This is a very stringent but realistic measure of

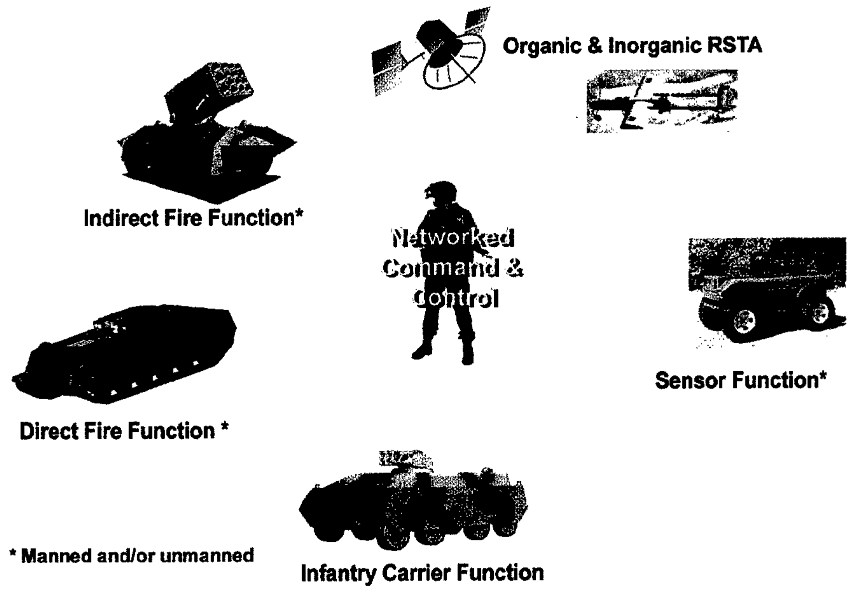


FIGURE I–5. DESIRED FCS FUNCTIONS

performance. The C–130-like transportability constraint for the FCS is the prime system characteristic to achieve the increase in strategic responsiveness stated in the Army Vision.

3 FCS Technology Areas

The Army, Defense Advanced Research Projects Agency (DARPA), and others will be developing a number of enabling technologies for FCS. In the case of the Army, these technologies will be transitioned either through planned Advanced Technology Demonstrations (ATDs) to the baseline FCS program or as future FCS block upgrades. These technologies fall into eight major areas and graphically depicted as flowing into the Force Transformation prism in Figure I–6.

The FCS technology areas shown in Figure I–6 are described below

- *Lethality:* Concepts include lethal and nonlethal line-of-sight and beyond-line-of-sight gun, missile, and directed-energy technologies that will allow the instantaneous prioritization, distribution, engagement, and destruction or neutralization of multiple targets. Technology must provide overmatching lethal capabilities to destroy heavy and light armor, bunkers, personnel, and air threats such as UAVs and rotary-winged aircraft. Representative programs include Compact Kinetic Energy Missile, Multirole Armament and Ammunition ATD, Direct-Fire Lethality ATD, Tank Extended-Range Munition, and Modernized Hellfire/Common Missile.
- *Army/DARPA Collaboration:* This represents the Army's contribution to the memorandum of agreement (MOA) between the Army and DARPA to collaboratively develop the FCS. This MOA was established in February 2000. The Army– DARPA FCS MOA outlines an S&T program leading to seamless transition of an FCS design and prototype Demonstrator to system development and demonstration (SDD) in FY2006. The SDD transition milestone decision will be made after the FCS integrated technology demonstration assessment of FCS to satisfy operational requirements. Key to the program's success is the simultaneous development of the operational concepts, requirements, and critical enabling technologies for achieving FCS combat overmatch capabilities.
- *Survivability:* Survivability is the primary technology challenge for a C–130 transportable ground combat system. To survive a first-round engagement, individual FCS platforms will require new approaches to hit avoidance and crew protection. Overall force survivability will

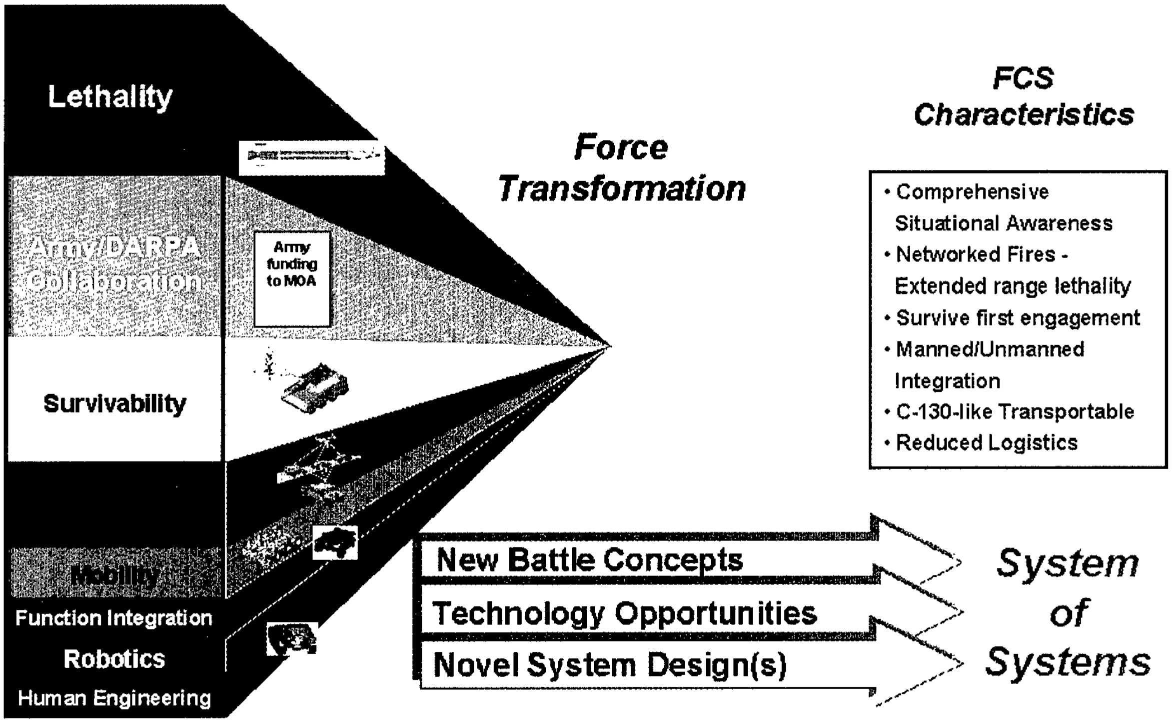


FIGURE I–6. FCS TECHNOLOGY AREAS, PARALLEL DEVELOPMENTS, AND DESIRED CHARACTERISTICS

require unprecedented battlespace situational understanding and standoff neutralization capability. Representative programs include Full-Spectrum Active Protection, Lightweight Armor, Vehicle-Mounted Mine Detection, and Signature Management Technology.

- *C⁴ISR:* Concepts include on-the-move, distributed command and control; multifunction sensors and sensor fusion algorithms; and development of a seamless tactical internet within and between units, leaders, soldiers, platforms, and sensors. Representative programs include Future Scout and Cavalry System ATD, Multifunctional On-the-Move Secure Adaptive Integrated Communications ATD, Agile Commander ATD, Tactical C^2 Protect ATD, and Integrated Situational Awareness and Targeting ATD.
- *Mobility:* Concepts include electric drives, pulsed power generation, hybrid propulsion, fuel cells, low-power demand electronics, and efficient power management. Representative programs include Combat Hybrid Power System, and Ground Propulsion and Mobility.
- *Function Integration:* This investment provides for the integration of Army-developed technologies into the DARPA-led FCS Demonstrator.
- *Robotics:* Unmanned vehicles must be employed to significantly enhance the effectiveness of manned systems. Unmanned aerial vehicles will increase the ability of forces to see before being seen. Unmanned ground vehicles will provide a significant component of the FCS ensemble and will reduce the risk to soldiers, alleviate personnel requirements for selected support functions, and increase strategic and tactical mobility through weight and size reductions. Representative programs include Robotic Follower ATD, Semiautonomous Robotics for FCS, and Demo III.
- *Human Engineering:* Concepts include human–machine interface designs that decrease task complexity and execution times, improve performance levels, and minimize physical, cognitive, and sensory demands; associate systems to offload human operators and enable maximum focus on the highest priority tasks; and embedded/deployable virtual training and mission rehearsal environments. Representative programs include Crew Integration and Automation Testbed, and Intravehicle Electronics Suite.

4 FCS Program

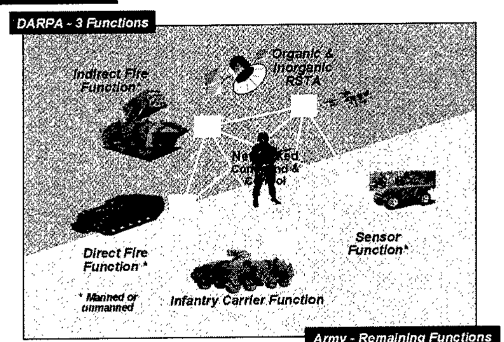
FCS concept development is underway. Both DARPA and the Army have explored options for meeting the stated program requirements. These studies have indicated that, with the development of a network-centric, distributed combat capability, it will be possible to provide a fighting force that is more lethal, survivable, mobile, and supportable than either the current heavy or the light force.

The FCS program strategy is shown in Figure I–7. The FCS concepts, technologies, and system designs will continue until FY2003. All three are being performed in parallel, as depicted in Figure I–6. The Army and DARPA are jointly funding the concepts and systems design work, as well as high-risk, high-payoff enabling technologies. Other FCS enabling technologies are being developed independently by the Army, industry, and other government agencies (e.g., the Department of Energy).

Focusing on FCS...
A Partnership with DARPA

DARPA | **High-Risk & Innovative Approaches**

- **DARPA/Army Collaborative Program**
- **Contracts for FCS Concepts, Designs, Demonstrations**
- **Demonstrates At Least Three Functions**
- **Provides Enabling Technologies for:**
  Networked Fires, Robotics, Unmanned Air/Ground Vehicles, Organic 3d Targeting and Mobile C3



Army | **Accelerate High-Payoff Core Technology**

- **Fund Integration of Remaining FCS Functions**
- **Army Develops Enabling Technologies for Enhanced Capability and Future Upgrades**

DARPA Leads FCS Design and Integrated Technology Demo

FIGURE I–7. FCS PROGRAM STRATEGY

FY2003 is a critical decision year. Using program results by that date, the Army leadership will decide if the FCS system-of-systems designs, and their associated technology breadboard demonstration, will fulfill the Army Vision. If they do, the program will continue by finalizing the approved FCS designs, bringing their requisite technologies to the prototype demonstration level, and building and testing an FCS Demonstrator. The FCS Demonstrator will be capable of performing all desired FCS functionalities described in the FCS mission needs statement (direct fire, indirect fire, air defense, nonlethal, reconnaissance, command and control on-the-move, and the ability to transport troops). The Demonstrator will be comprised of enabling technologies developed and provided by the Army 6.3 program, DARPA, and others. This Demonstrator will be completed and tested in FY2006, and the results provided to the Milestone Decision Authority for use in the FCS SDD decision.

By mid FY2006, FCS will undergo a Milestone B decision review and formally enter into SDD. For those technologies not ready for the SDD phase, but which will provide enhanced FCS per-

formance and functionality in the future (e.g., electromagnetic gun), the S&T community will continue research and technology maturation to support FCS block upgrades.

5 Objective Force Task Force

An Objective Force Task Force has been created to accelerate the progression of FCS and other Objective Force systems to production status. The Task Force director will report to the Secretary of the Army through the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) and to the Chief of Staff, Army through the Vice Chief of Staff, Army (VCSA). Through coordination and assessments, the Objective Force Task Force will expedite FCS-related efforts in the concepts, requirements, S&T, and acquisition communities. The Task Force will be responsible for reporting FCS design and technology readiness to the senior Army leadership for the Technology Readiness Decision in FY2003. In FY2004, the Task Force will focus on achieving success of the FCS Demonstrator phase and support a transition to SDD in FY2006. Key Task Force tasks are to develop and maintain the FCS Campaign Plan to include execution and decision support matrices; synchronize the FCS Campaign Plan with the Army Transformation Campaign Plan; develop and maintain a Fielding Implementation Plan, which includes but is not limited to describing the overall FCS acquisition strategy, the FCS Master Schedule, and near-term technology developments that are intended to transition to SDD in FY2006; and ensure FCS integration into the Objective Force.

6 Other S&T

A small portion of the S&T program is devoted to several programs that do not directly support the Objective Force but are valuable for other Army and national interests:

- *Environmental Quality*—Tools and techniques to enhance "green" operations through improved pollution prevention, restoration of contaminated areas, enhanced compliance with environmental statutes and regulations, and effective conservation of resources.
- *Engineering Construction*—Research and technology to achieve critically needed cost reductions in Army facility life-cycle processes (infrastructure planning, assessment, design, construction, revitalization, sustainment, and disposal) to improve soldier readiness, safety, and quality of life.
- *Dual-Use S&T*—Coinvestment with industry in technologies with both military and commercial applicability, thereby reducing development costs and potentially reducing production costs through shared production lines.
- *Materials Processing*—Widely applicable novel techniques for materials processing and production.

D S&T PLANNING AND OVERSIGHT

The Army's Science and Technology program, as reflected in this ASTMP, identifies the S&T investments needed to achieve the Army Vision. In this sense, the ASTMP is the action plan for mobilizing government, industry, and academic resources. The ASTMP position in the overall DoD strategic planning hierarchy is shown in Figure I–8. Army leadership oversight of the Army S&T program is provided by the Army Science and Technology Advisory Group (ASTAG), which is co-chaired by ASA(ALT) and VCSA (Figure I–9).

The Army Science and Technology Working Group (ASTWG) is co-chaired by the Deputy Assistant Secretary for Research and Technology (DAS(R&T)) and the Assistant Deputy Chief of Staff for Programs–Force Development (DCSPRO–FD). The ASTWG provides Two-Star-level resolu-

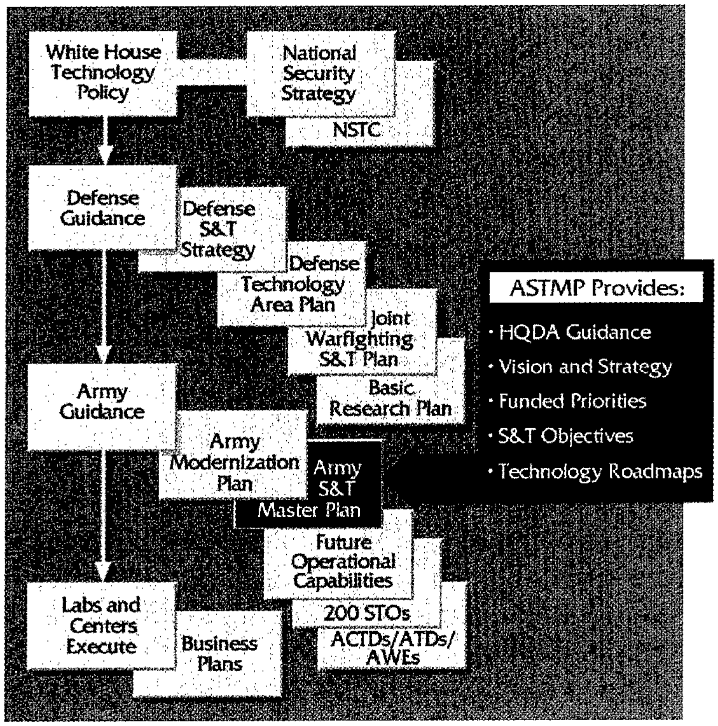


FIGURE I–8. HIERARCHY OF PLANS

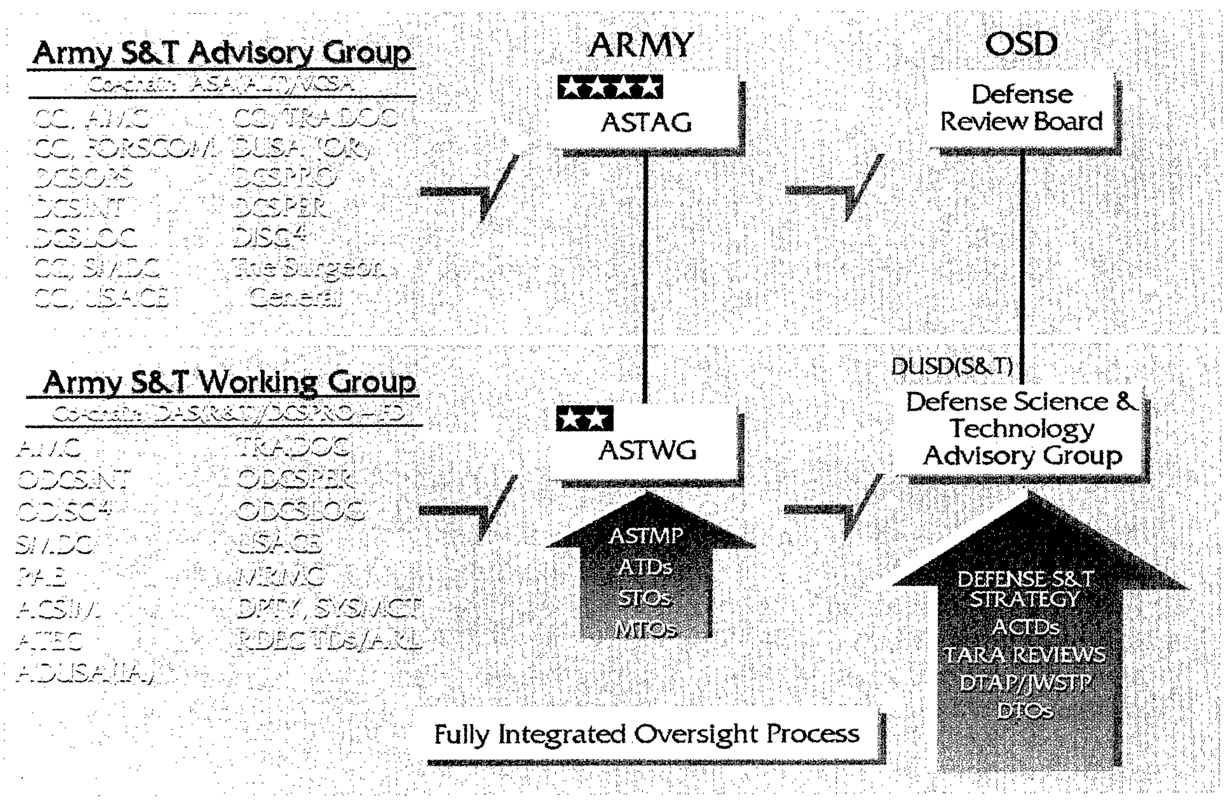


FIGURE I–9. ARMY SCIENCE AND TECHNOLOGY OVERSIGHT

tion of pressing S&T issues; recommends to the ASTAG revisions to the Army's S&T vision, strategy, principles, and priorities; and reviews and approves ATDs, Science and Technology Objectives (STOs), and Manufacturing Technology Objectives (MTOs). Underneath the ASTWG is the Warfighter Technical Council (WTC), a One-Star-level group tasked with performing the detailed review and assessment of all proposed and ongoing STOs, ATDs, and Advanced Concept Technology Demonstrations (ACTDs). The WTC provides the results of its work, with its recommendations, to the ASTWG for guidance and approval. The WTC is co-chaired by the Director of Technology, Office of the DAS(R&T), and the U.S. Army Training and Doctrine Command (TRADOC) Assistant Chief of Staff, Combat Development, and is comprised of senior representatives from the major commands (MACOMs). Assisting the WTC in an advisory capacity are the technical directors from the various Army laboratories and research, development and engineering centers (RDECs). The entire planning process for the Army S&T program is shown in Figure I–10, including the individual review and prioritization process by TRADOC and the MACOMs. The process to bring MTOs to the ASTWG is similar to that of the STOs, but uses a ManTech Technical Council co-chaired by the Director for Research, Office of the DAS(R&T), and the Assistant Deputy Chief of Staff, Research, Development, and Acquisition, U.S. Army Materiel Command (AMC). The council also has representatives from DCSPRO, Deputy for Systems Management and Horizontal Technology Integration, and the Office of the

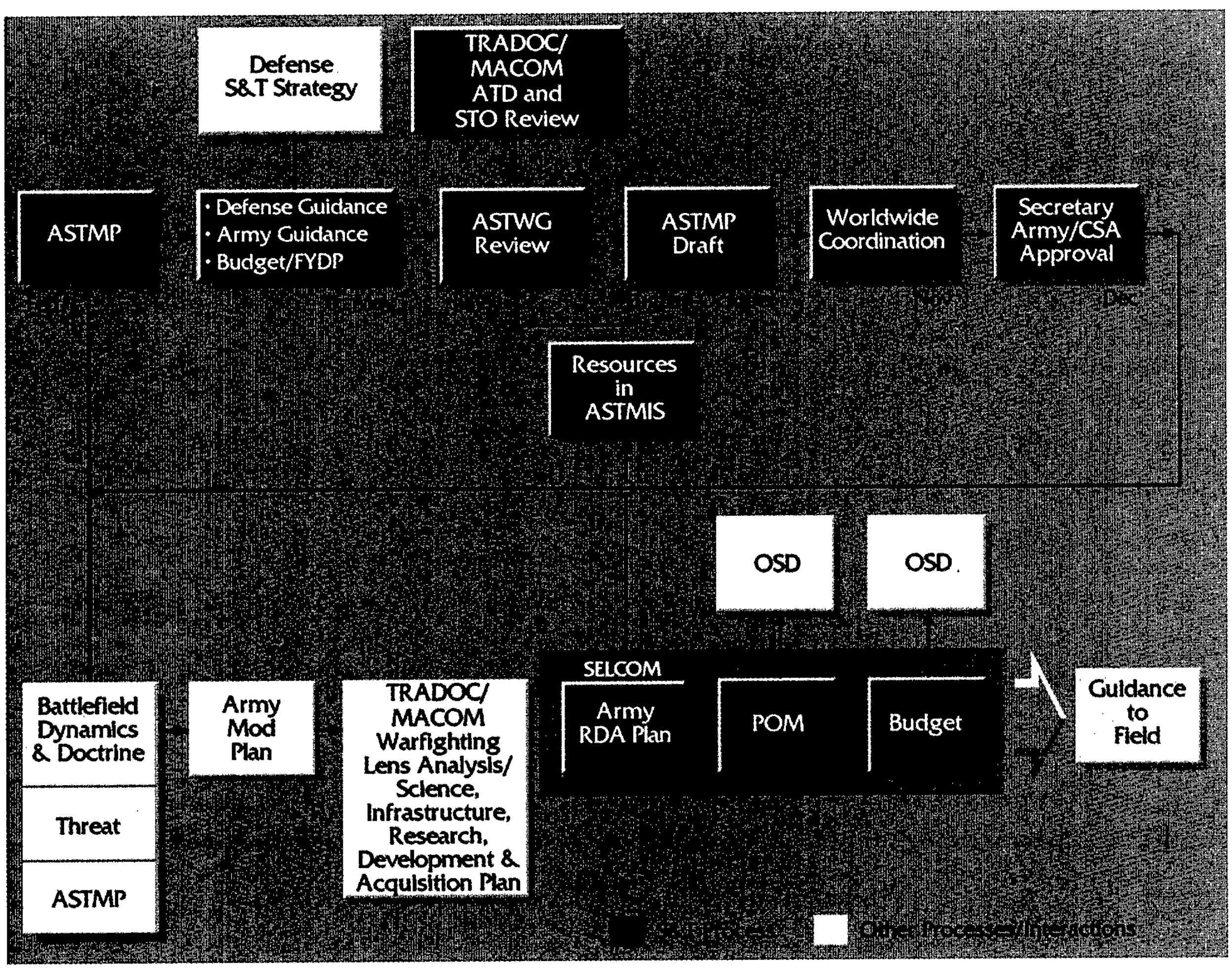


FIGURE I–10. ARMY SCIENCE AND TECHNOLOGY PLANNING PROCESS

DAS (Plans, Programs, and Policy). The preparation and approval of the ASTMP is shown in the upper part of the diagram, and its progress through the overall Army planning and budgeting process is shown in the lower part.

E BUILDING BLOCKS OF THE S&T PROGRAM

1 Science and Technology Objectives

STOs are the fundamental "building blocks" of the Army S&T program. These are the highest priority top-level efforts in the advanced technology development and applied research programs. To promote innovation and competition, STOs are limited to a maximum of 200 in each ASTMP. A STO states a specific, measurable (by technical readiness levels), major technological advancement to be achieved by a specific fiscal year. Figure I–11 graphically depicts the elements of a STO. STOs must be consistent with the funding available in the current year budget, the Future-Years Defense Plan (FYDP), and the Program Objective Memorandum (POM). Not every worthwhile funded 6.2 and 6.3 technology program is cited as a STO.

The Army uses the STOs to focus and stabilize the 6.2 and 6.3 program, practice management by objectives, and provide feedback to Army scientists and engineers regarding their productivity and customer satisfaction. STOs are reviewed annually at a joint materiel developer/TRADOC meeting and then reviewed and approved by the ASTWG (Figure I–12). STOs, revised as necessary to maintain currency and consistency with economic factors, ensure TRADOC input to the planning process, and provide Army leadership guidance to S&T performing organizations. All Army Planning, Programming, Budgeting, and Execution System submissions, including budget estimates, execution plans, and Defense Technology Objectives (DTOs), should comply with the STO guidance. Descriptions of current STOs are given in Volume II, Annex A, of this document and in the Army Science and Technology Management Information System (ASTMIS).

2 Advanced Technology Demonstrations

Advanced Technology Demonstrations are technology demonstrations characterized by:

- Being relatively large scale in resources and complexity but typically focused on an individual system or subsystem.
- Operator/user involvement from planning to final documentation.
- Testing with soldiers in a real or synthetic operational environment.
- Exit criteria approved by both the materiel developer and TRADOC.
- Finite schedule, typically 5 years or less.
- Having cost, schedule, and objective performance baselines in an Advanced Technology Demonstration Management Plan (ATDMP) approved by DAS(R&T).

Each ATD is designed to meet or exceed exit criteria agreed upon by the warfighter and ATD manager at program inception. These must be met before the technology in question can transition to development. The ATDMP approval process is shown in Figure I–13.

ATDs seek to demonstrate the potential for enhanced military operational capability or cost effectiveness. Active participation by a TRADOC school, as well as the materiel developer, is required throughout the demonstration. At least one demonstration at a TRADOC battle lab, as

ASTMP Reference

Objective

III.WP.1999.01. Multirole Armament and Ammunition ATD

The STO objective is to develop and demonstrate a lightweight, multimission armament system and munition suite for the FCS. This effort will incorporate force-level trade studies, mission requirements analysis, and demos of major component technologies. In FY01, complete review of mission requirements, design of cannon, autoloader, fire control, electrothermal-chemical (ETC) propulsion and turreted armament system; advanced KE design and initial MP-extended-range munition (ERM) and Smart Cargo designs; warhead development of a compact shaped charge (SC) and GENII/Collinear explosively formed penetrator (EFP). In FY02, complete mfg of lightweight cannon, autoloader, fire control, ETC propulsion and turreted armament system; conduct limited gun testing of KE composite sabot; complete Smart Cargo and MP-ERM projectile design and laboratory demos of SC and EFP warheads (TRL 5). In FY03, conduct system component critical demonstrations; complete system integration laboratory demo of fire control functionality; complete functional demos of launcher/autoloader concepts and turret mfg/integration; demo composite sabot with integration of novel penetrator; conduct MP-ERM armor and high-g tests; conduct Smart Cargo component high-g tests; initiate optimization of SC and EFP warheads in prototype FCS designs (TRL 5). In FY04, conduct full-up integrated turret system (turret slew, gun elevation, and autoloader feed rate) and firing demonstration of ETC propulsion for KE projectile; demo KE projectile flight and armor defeat vs. 4-km target; conduct MP-ERM seeker high-g tests and guide-to-hit demonstration; complete Smart Cargo component high-g testing; complete optimization of SC and EFP warheads; demo high energy less sensitive explosive (TRL 6). In FY06, complete systems-level live fire demo of ammo suite—less Smart Cargo round (TRL 6). In FY07, complete demo of Smart Cargo round (TRL 7).

Intermediate Milestones

Final Product With Metrics

Supports: PM Future Combat Systems, TRADOC/TSM FCS

Applications

Points of Contact

Technology Staff Officer:	TRADOC:	STO Manager:
John Appel	COL Rodriguez	Mark Ford
SAAL-TT	FCS TSM	ARDEC
703-601-1537	757-727-2217	973-724-3425
appelj@sarda.army.mil	rodriguj@monroe.army.mil	mford@pica.army.mil

FIGURE I–11. ANATOMY OF A STO

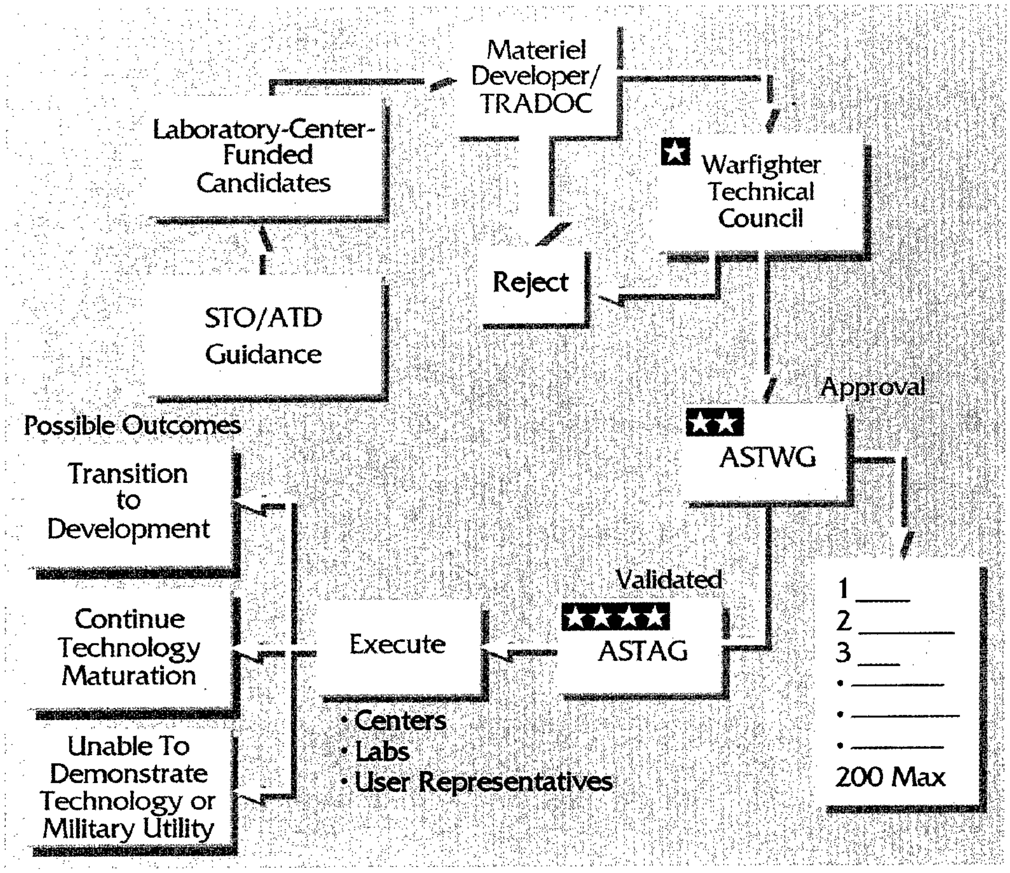


FIGURE I–12. SCIENCE AND TECHNOLOGY OBJECTIVE PROCESS

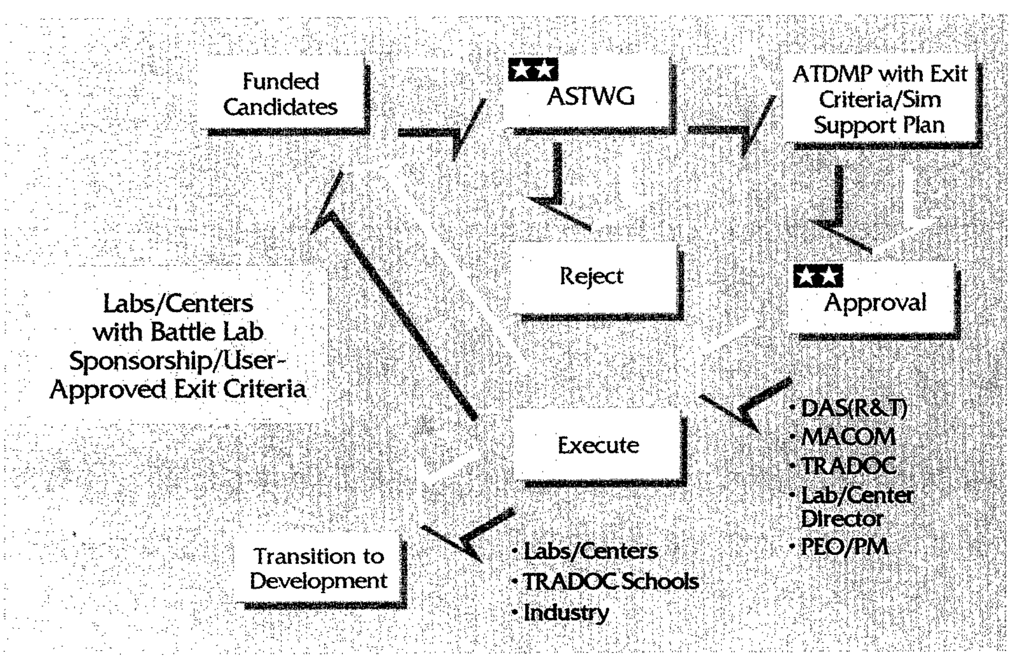


FIGURE I–13. ARMY ATDMP APPROVAL PROCESS

well as an advanced simulation, is required. This helps the TRADOC schools develop more informed requirements and the materiel developer reduce risk in the system development and demonstration phase. Current Army ATDs are listed in Table I–1.

TABLE I–1. CURRENT ARMY ATDS

Advanced Technology Demonstrations	Years
LIGHT FORCE LETHALITY AND AGILITY	
Precision-Guided Mortar Munition	FY94–01
Multimission/Common Modular Unmanned Aerial Vehicle Sensors	FY97–01
Air/Land Enhanced Reconnaissance and Targeting	FY97–01
Tactical Command and Control Protect	FY98–02
Multifunction Staring Sensor Suite	FY98–03
Integrated Situation Awareness and Targeting	FY99–02
Objective Crew-Served Weapon	FY99–02
Advanced Night Vision Goggles	FY00–03
Agile Commander	FY00–04
Multifunction On-the-Move Secure Adaptive Integrated Communications	FY00–04
HEAVY FORCES DEPLOYABILITY	
Direct-Fire Lethality	FY96–01
Future Scout and Cavalry System	FY98–02
Crew Integration and Automation Testbed	FY00–04
Robotic Follower	FY01–05
Multirole Armament and Ammunition	FY01–07
REDUCED LOGISTICS	
Enhanced Trafficability and Sea State Mitigation	FY99–02
Logistics Command and Control	FY99–03
Low-Cost Precision Kill 2.75-Inch Guided Rocket	FY99–03

3 Advanced Concept Technology Demonstrations

Advanced Concept Technology Demonstrations provide a mechanism for intense involvement of the warfighters while incorporation of technology into a warfighting system is still at an informal stage. This allows iterative change of both the system construct and the user's concept of operation without the constraints and costs that are incurred when the discipline of formal acquisition is involved. ACTDs are user oriented, even user dominated.

The ACTD has three driving motivations: (1) to have the user gain an understanding of the military utility before committing to large-scale acquisition, (2) to develop corresponding concepts of operation and doctrine that make the best use of the new capability, and (3) to provide limited, initial residual operational capabilities to the forces. ACTDs are of sufficient scope and scale to establish military utility. The operational unit is left with a residual capability for continued use for up to 2 years. This provides a significant improvement in the ability to refine the tactics and gain further insight into the potential utility and impact on doctrine. The ACTD process is shown in Figure I–14. All Army ACTD proposals must now have the approval of the

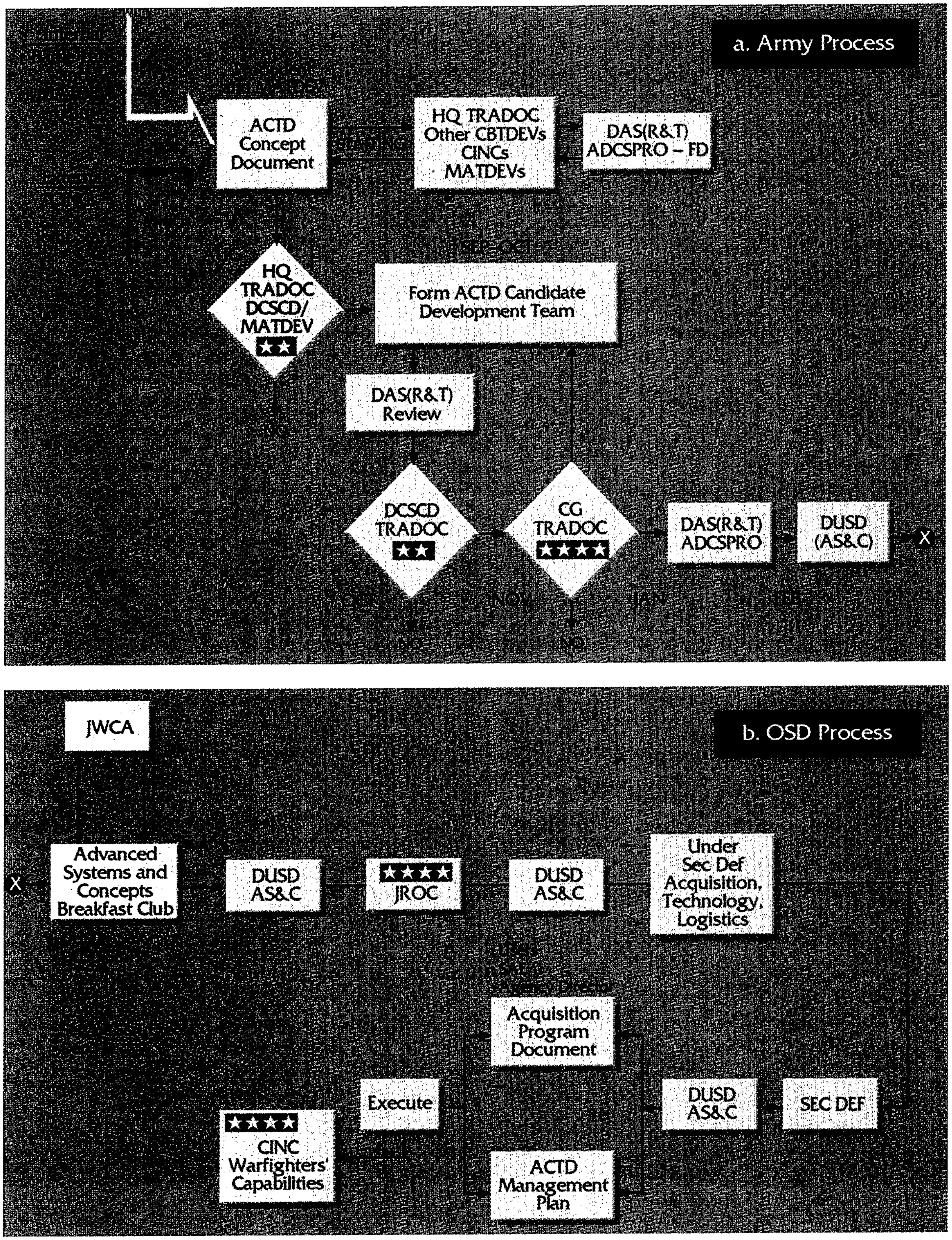


FIGURE I–14. ACTD PROCESS

commander of TRADOC. In the Army, ACTDs primarily involve system-of-systems demonstrations incorporating individual equipment developed under ATDs.

Formal requirements for the operational forces are typically generated during the ACTD after military utility has been demonstrated. The outcome of an ACTD is determined by the conclusions of the participating users. If the user is not prepared to initiate acquisition, the effort will be terminated. If, on the other hand, the user determines that the demonstrated concept should be brought into the forces, there are two possible avenues. If large numbers are required, the system should enter the acquisition process at whatever stage good judgment dictates. If only small numbers are required, it is preferable to modify the demonstration system appropriately and then to replicate it as needed. This latter avenue might apply to C^3, surveillance, and special operations equipment, as well as to complex software systems where evolutionary development and upgrading is preferred. Army ACTDs are described in Volume II, Annex C.

In FY01, the Army is managing seven S&T-funded ACTDs: Line-of-Sight Antitank (LOSAT); Theater Precision Strike Operations; Military Operations in Urbanized Terrain; Joint Continuous Strike Environment; Joint Medical Operations–Telemedicine; Joint Intelligence, Surveillance, and Reconnaissance; and Rapid Terrain Visualization. Most of these ACTDs are composed of one or more Army STOs. Figure I–15 illustrates some of the features of the LOSAT ACTD—the single largest Army S&T investment for FY01.

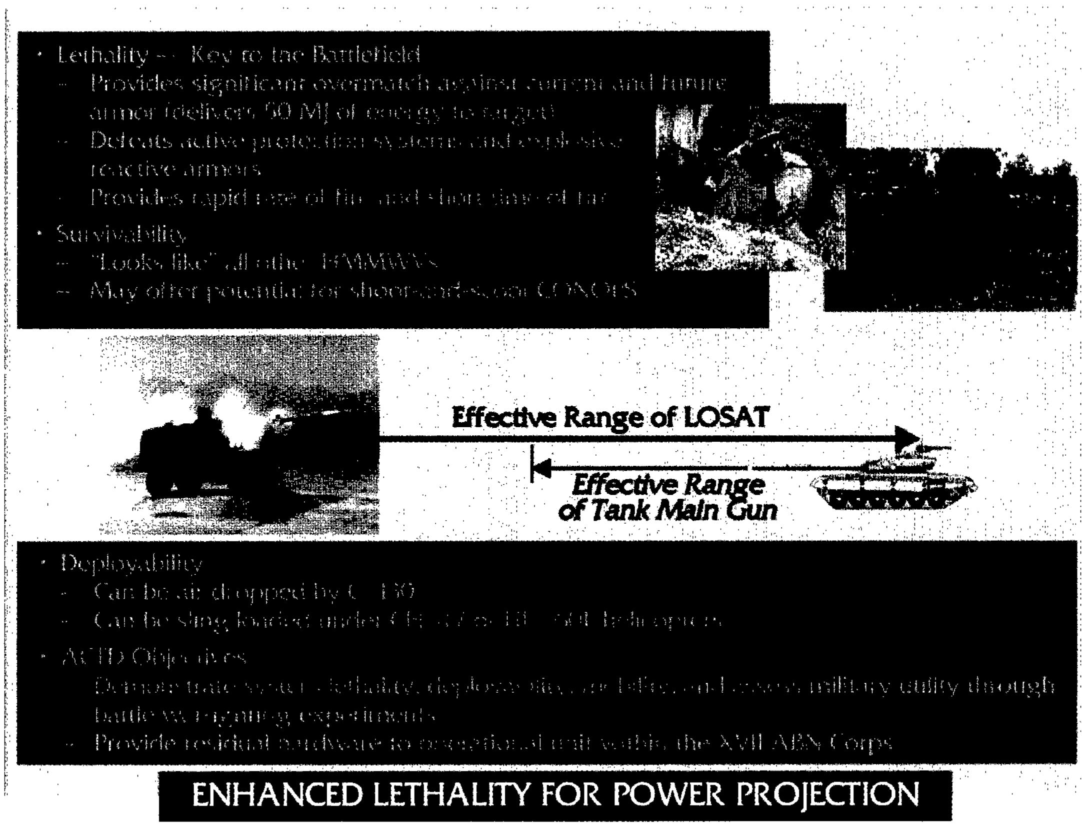


FIGURE I–15. LOSAT ACTD CHARACTERISTICS

4 Strategic Research Objectives

Strategic Research Objectives are basic research initiatives designed to establish a major, synergistic research effort that will produce significant advancements in the state-of-the-art in the disciplines being researched. Army SROs are directed primarily toward areas with high payoff for future Objective Force applications and are designed to promote a stable funding base for sustained investment for long-term (5–10 years) scientific investigations. SROs are intended to provide a clear focus for the Army's basic research program and to tie these investments to specific technology advances needed to enable the future Army.

The Department of Defense has defined six DoD-wide Strategic Research Areas (SRAs, equivalent to SROs) in which the Army has a significant role: biomimetics, nanoscience, smart structures, information technology, intelligent systems, and compact power sources. In addition to the six SRAs, the ASTWG approved three additional Army-specific SROs in 1998: Armor Materials by Design, Enhancing Soldier Performance, and Microminiature, Multifunctional Sensors.

These nine Army SROs currently represent approximately 25 percent of the Army's 6.1 investment. To ensure an appropriate, long-term focus for the 6.1 program, the goal is to increase this to between 40 and 50 percent of the Army 6.1 program. This will be accomplished by increasing investments in existing SROs and establishing additional SROs, as appropriate.

F S&T PROGRAM CHARACTERISTICS

— Focused —

S&T investments are the catalysts of activities to provide the material solutions that will transform the Army of today into the Objective Force. Today's S&T investments are critical to achieving the revolutionary enhancements in warfighting capability required for the future. One method that has proved effective in the management of the S&T program to assess responsiveness is the use of Independent Review Teams. External reviewers assess program focus, direction, and quality, and recommend "a way ahead" in specific technology areas. Such an outside perspective is critical to ensure that the Army avoids "stovepiping" and exploits appropriate opportunities.

— Innovative —

The Army implements innovative tools, processes, and partnerships to ensure that technology investments are focused on the right areas and to leverage the work and resources of others to meet Army requirements. The Army collaboration with DARPA on the FCS program is a clear example. The Army entered into this partnership because of DARPA's reputation for pushing the technology envelope and for the opportunity to apply the combined resources of DARPA and the Army on this important initiative. Another example of innovation is the Institute for Creative Technologies at the University of Southern California. This University-Affiliated Research Center (UARC) is a strategic partnership that will allow the Army to leverage the resources of the entertainment and game industry to foster advances in simulation and virtual environment technologies for application to soldier, leader, and unit warfighter training.

— Balanced —

The S&T program balances risk, technological developments, military payoffs, and especially time—immediate contributions to today's Army through basic research needed to enable capabilities 20 years in the future. The balance among these investments is driven by the need to be responsive to warfighter requirements and the responsibility to maintain a long-term perspective that encompasses technological opportunities.

— Technology Transition —

The number of major weapon system new starts will decrease substantially during this decade, while increased reliance will be placed on technology insertion into existing systems via such upgrading mechanisms as engineering change proposals, product improvement proposals, and block improvement and multistage improvement programs.

Technology Readiness Levels. In early 2000, the DAS(R&T) formally mandated the use of technology readiness levels (TRLs) to define the maturity of technologies in Army S&T programs. The TRLs and the accompanying definitions are adapted from NASA. The Government Accounting Office (GAO) report, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes,* in July 1999 recommended the use of TRLs. That report stated, ". . . that demonstrating a high level of maturity before new technologies are incorporated into product development programs puts those programs in a better position to succeed." Levels range from one, basic concept, to nine, proven in its final form:

- TRL 1—Basic principles observed and reported.
- TRL 2—Technology concept and/or application formulated.
- TRL 3—Analytical and experimental critical function and/or characteristic proof of concept.
- TRL 4—Component and/or breadboard validation in laboratory environment.
- TRL 5—Component and/or breadboard validation in relevant environment.
- TRL 6—System/subsystem model or prototype demonstration in a relevant environment.
- TRL 7—System prototype demonstration in an operational environment.
- TRL 8—Actual system completed and "flight qualified" through test and demonstration.
- TRL 9—Actual system "flight proven" through successful mission operations.

The purpose in using the GAO-recommended criteria is to clearly describe the level of maturity and risks prior to entering the system development and demonstration phase of systems acquisition. Current guidance emphasizes transitioning 6.3 STOs only after achieving TRL 6, unless the program is an ATD, then transition is set at TRL 6/7. TRLs are defined in more detail in Volume II, Annex A.

G RESOURCING THE STRATEGY

The Army policy is to maintain stable funding for Army S&T. This stability principle of our investment strategy is consistent with the long-term nature of basic and applied research. Stability of focus and funding permits Army's scientists and engineers to conduct meaningful long-range planning to ensure that the technologies required to address future warfighting needs and obtain Objective Force goals will be available when needed.

Army S&T is funded in three budget activities: 6.1 Basic Research, 6.2 Applied Research, and 6.3 Advanced Technology Development. Figure I–16 shows how the 6.1, 6.2, and 6.3 funding categories relate to the overall acquisition process. The milestone phases of the acquisition process reflect the revised DoDI 5000.2, *Defense Acquisition System,* approved in October 2000. S&T funding precedes the Milestone B decision that approves entrance into systems development and demonstration.

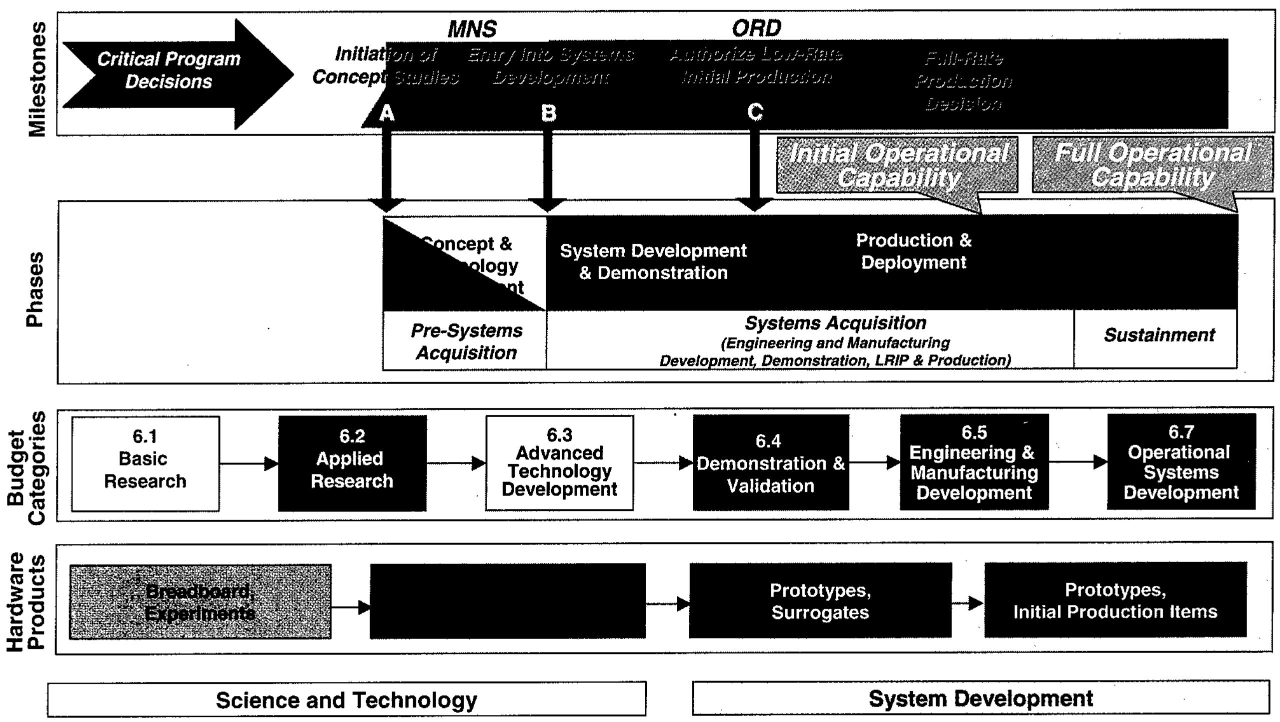


FIGURE I–16. SCIENCE AND TECHNOLOGY RELATED TO THE ACQUISITION PROCESS

Basic research (6.1) includes all efforts of scientific study and experimentation with a high potential to significantly improve land warfighting capabilities. In the basic research category (6.1), the Army maintains a strong peer-reviewed scientific base providing the foundation for technological improvements to warfighting capability through university and in-house research. In addition to conducting in-house research, Army scientists monitor developments in academia and industry and evaluate the many proposals received for 6.1 funds. (See Chapter V.)

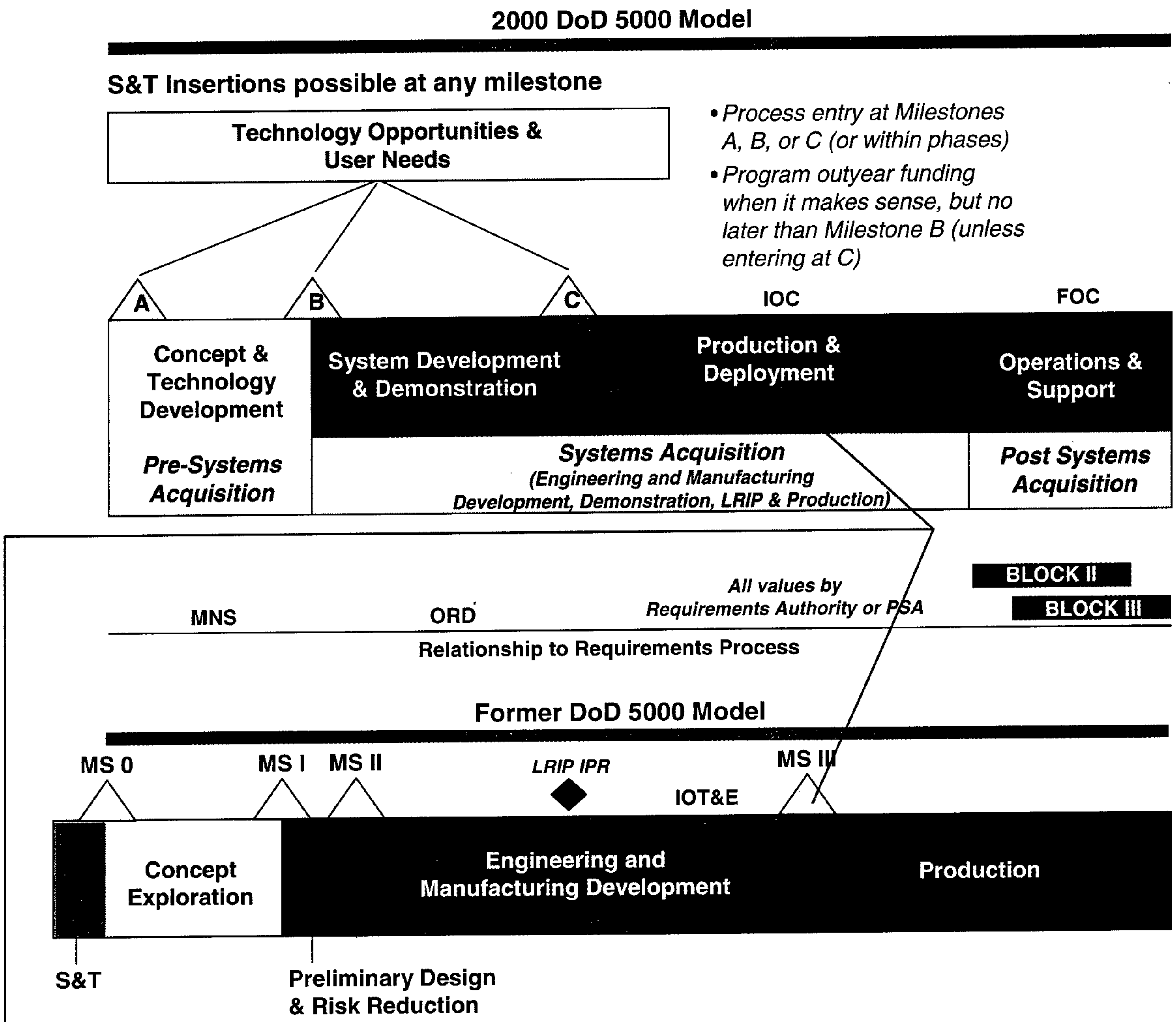
Applied research (6.2) includes all efforts directed toward the solution of specific military problems, short of major demonstrations and development projects. This applied research category includes the development of components, models, and new concepts through in-house and industry efforts. Individual research programs often enable a variety of new systems and support a number of identified needs. Since research programs may readily contribute to needs in several mission areas, the Army performs horizontal integration, or "cross-mission-area analyses," to understand 6.2 funding priorities. (See Chapter IV.)

Advanced Technology Development (6.3) includes all efforts directed toward projects that have moved into demonstration of hardware or software for operational feasibility. In the 6.3 category, experimental systems or subsystems are demonstrated to prove the technical feasibility and military utility of the approach selected. Advanced technology development (6.3) provides the path for the rapid development and demonstration of new components and systems. The Army establishes priorities for demonstrations that are consistent with priorities for system development and demonstrations and procurement needs described in the *Army Modernization Plan.* (See Chapter III.)

Figure I–17 compares the new (2000) DoD 5000 acquisition phases to the former acquisition model. Note that technology can be inserted into a program at any milestone decision (A, B, or C) depending on maturity. In the former acquisition process, S&T activities occurred before Milestone 0—the concept exploration phase. The new DoD 5000 promotes faster insertion of advanced technology into the design and development of systems.

H SUMMARY

The Army S&T program is boldly responding to the challenges of the Army Vision. To have an agile and innovative program, the Army is seeking and responding to the insights of independent, external examinations of the program. The CSA charged the S&T community with leading the transformation of the Army into a full-spectrum force for the 21st century. The Army has accepted the challenge and is focusing all resources to meet it.



The most important milestone for S&T is Milestone B, which transitions mature technology to the PM to begin SDD for the program.

The "new" model defines the major milestone as Milestone C, which is the decision to enter low-rate initial production (LRIP). IOT&E must be completed before the full-rate decision in both models.

FIGURE I–17. COMPARISON OF OLD AND NEW DOD 5000 ACQUISITION MODELS

CHAPTER

II

TRAINING AND DOCTRINES COMMAND'S ROLE IN SCIENCE AND TECHNOLOGY

CONTENTS

A TRADOC—THE ARMY'S GATEKEEPER FOR WARFIGHTING REQUIREMENTS II–1

1 Staff Lead for Science and Technology II–1

2 Warfighting Experimentation II–2

B SPECIFIC TRADOC S&T ACTIVITIES II–2

1 Basic Research Interaction II–2

2 Strategic Research Objectives Review II–2

3 Advanced Concept Technology Demonstration II–2

4 Science and Technology Objective Review II–3

5 Advanced Technology Demonstration Review II–3

6 Warfighting Rapid Acquisition Program II–3

7 Advanced Concepts and Technology II Program II–3

8 Small Business Innovation Research Program II–4

9 Warfighter/Technical Council and Army Science Technology Working Group II–4

C SUMMARY II–4

CHAPTER

II TRAINING AND DOCTRINE COMMAND'S ROLE IN SCIENCE AND TECHNOLOGY

A TRADOC—THE ARMY'S GATEKEEPER FOR WARFIGHTING REQUIREMENTS

TRADOC represents both the warfighter and the user in its role as the Army's architect of the future. As such, TRADOC has the responsibility to influence the Army's science and technology (S&T) program from the perspective of the user, the soldiers, and leaders who must employ warfighting capabilities. One of its key roles is to oversee the development of all Army warfighting requirements. In October 1999, the Army adopted a new vision for the future. An integral part of this vision is the Army Transformation Campaign Plan (ATCP), which coordinates the development and implementation of this vision. TRADOC has a central role in achieving the goals of the ATCP. TRADOC assesses the Army's missions and the operational environment in a process that develops operational and organization (O&O) concepts. The O&O concepts articulate the operational capabilities and identify requirements across doctrine, training, leader development, organizations, material, and soldiers (DTLOMS) to achieve these operational capabilities. As the Army executes this transformation process, significant activity will occur in both the S&T and the requirements determination process.

Accordingly, TRADOC has approval authority for all Army warfighting requirements, which are then submitted to the Department of the Army.

1 Staff Lead for Science and Technology

Within Headquarters TRADOC, the Deputy Chief of Staff for Combat Developments (DCSCD) is responsible for TRADOC's involvement in S&T processes. Within DCSCD, the Director, Experimentation, Operation, and Integration Directorate oversees the TRADOC S&T processes and coordinates day-to-day S&T staff actions. DCSCD is also responsible for producing concepts for Objective Force capabilities (OFCs), formally referred to as future operational capabilities (FOCs).

The current TRADOC Pamphlet (TP) 525–5, "Force XXI Operations," published in 1994, provides a capstone concept for future warfighting. This publication is currently undergoing revision and will be titled, "Advanced Full-Spectrum Operations." The Capstone Concept is the basis for FOCs, which are consolidated in TP 525–66, "Future Operational Capabilities." FOCs are structured statements of operational capability requirements that provide a foundation for requirements determination activities. The revised TP 525–66, "Objective Force Capabilities," will guide the Army's S&T investment.

TRADOC functional directorates participate in the S&T process by providing periodic reviews of new technology enhancements and research areas.

2 Warfighting Experimentation

Warfighting experimentation and analysis provide key insights into future warfighting concepts and technology as well as the requirements determination process. When properly planned and executed, they give the Army an unsurpassed means to understand future warfighting requirements within all DTLOMS domains.

B SPECIFIC TRADOC S&T ACTIVITIES

To provide insights to the materiel developer (MATDEV) community, TRADOC conducts a series of reviews: the Strategic Research Objective (SRO) review, the Science and Technology Objective (STO) review, the Advanced Technology Demonstration (ATD) review, and the Special Access Program Oversight Committee review. TRADOC also executes a variety of other programs, processes, and interactions that assist in developing future force insights. Interactions with the Defense Science Board (DSB), the Army Science Board (ASB), and the Director of the Defense Advanced Research Project Agency (DARPA) provide an opportunity to discuss a variety of strategic issues and opportunities. Periodic meetings with Department of Energy (DOE) laboratories, Army federated laboratories, and academia foster a partnership with other research facilities whose programs offer leveraging opportunities. The Advanced Concepts and Technology II (ACT II), Warfighting Rapid Acquisition Program (WRAP), and the Small Business Innovation Research (SBIR) programs assists the combat development (CBTDEV) community in viewing and testing currently available technologies. Semiannual Army Materiel Command (AMC)/TRADOC partnership meetings provide a forum to discuss the tough issues facing the CBTDEV and MATDEV communities in the Army today.

1 Basic Research Interaction

TRADOC is involved in focusing basic research through the annual assessment of the DoD SROs, the emerging Army-specific SROs, and interactions with DARPA, DSB, ASB, DOE laboratories, and federated laboratories.

2 Strategic Research Objectives Review

The SROs look deep into the future to develop those research areas today that are anticipated as necessary in the future. TRADOC participates in the Triennial Basic Research Review, which is conducted to assess the current set of DoD SROs. On an annual basis, HQ TRADOC, DCSCD, and the Deputy Chief of Staff for Doctrine (DCSDOC) will review, evaluate, and prioritize the emerging Army SROs for consideration by the Army Science and Technology Working Group (ASTWG).

3 Advanced Concept Technology Demonstration

Advanced Concept Technology Demonstrations (ACTDs) accelerate the application of mature technologies response to a critical military operational need. They provide an evaluation of the military utility of proposed solutions and are jointly planned by users and technology developers to enable operational forces to experiment in the field with new technologies and to evaluate potential changes to doctrine, warfighting concepts, tactics, modernization plans, and training. ACTDs are used to develop appropriate concepts of operation, provide insights for the generation or refinement of requirements, and provide residual operational capabilities to the sponsor-

ing user for an extended user evaluation on a contingency operational deployment. TRADOC plays a significant role in the ACTD nomination and approval process. TRADOC provides operational managers for the Army-led ACTDs and requirements integration managers for other service- and agency-led ACTDs. This process is described in detail in TP 71–9, Chapter 8–7.

4 Science and Technology Objective Review

Recommended STOs are submitted by AMC, Corps of Engineers, Army Medical Research and Materiel Command (MRMC), Army Space and Missile Defense Command, Army Research Institute for the Behavioral and Social Sciences, and other Army laboratories. STOs are reviewed annually by TRADOC for warfighting relevance and importance. TRADOC, along with the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)), the Army Staff, and the MATDEVs, recommend STOs for continuation, restructure or deletion, and prioritization of new STO nominations.

5 Advanced Technology Demonstration Review

The objective of ATDs is to demonstrate the potential of mature technology from STOs or other work packages to provide enhanced military operational capability or greater cost effectiveness. ATDs must evaluate technical performance against specific exit criteria. These S&T-funded experiments are conducted in operational, not laboratory, environments over 3 to 5 years. Ideally, experimental results transition into current system improvements or new acquisition programs. ATDs are reviewed annually by AMC, Corps of Engineers, Army MRMC, DA Deputy Chief of Staff for Programs, ASA(ALT), and a TRADOC Warfighting Council for relevance and technology advancement. ATDs are approved by the Army Science and Technology Working Group. Each ATD must meet or exceed exit criteria agreed upon by the warfighter and the ATD manager at program inception (well before tests begin) and before the technology in question will transition to development.

6 Warfighting Rapid Acquisition Program

The purpose of WRAP is to provide a means of accelerating procurement of systems identified as compelling successes in warfighting experiments. WRAP policy indicates that systems can be identified through Concept Experimentation Programs (CEPs), Advanced Technology Demonstrations (ATDs), Advanced Concepts and Technology II (ACT II), and Advanced Warfighting Experiments (AWEs). WRAP provides 2 years of near-term funding and is essentially a bridge allowing systems to be accelerated while avoiding the inherent delay of the normal budgeting process.

The Army's current vision of lighter, more lethal forces requires the Army to begin experimenting and equipping units to meet the new vision. The WRAP program has proven itself as a means of expediting new technologies.

7 Advanced Concepts and Technology II Program

The ACT II Program is an innovative approach to exploring technology solutions to warfighting requirements. Through the Army battle labs, ACT II provides users direct access to industry's innovative ideas to help maintain America's Army as the dominant, decisive land force of the 21st century. The Army selects industry's most promising technologies, prototypes, and nondevelopmental items that have the greatest potential to meet future warfighting needs.

To assess the warfighting benefits of their new ideas, Army battle labs provide industry with realistic, soldier- and leader-in-the-loop demonstration environments that replicate rigorous battlefield dynamics. The ACT II partnership between the warfighter, MATDEV, and industry is a key enabler for the Army's "strategic scouts" of the future—the battle labs.

8 Small Business Innovation Research Program

The Army SBIR program identifies and funds innovative projects proposed by small businesses in response to research or research and development topics generated by the Army. It is designed to provide Army laboratories and research, development, and engineering centers (RDECs) a means of leveraging the efforts of small, high-technology companies to support critical Army needs.

9 Warfighter/Technical Council and Army Science Technology Working Group

The Warfighter/Technical Council (WTC) is a one-star-level review body cochaired by the ASA(ALT) Director for Technology and the TRADOC Assistant Deputy Chief of Staff, Combat Development with SES-level members from the Army laboratories and RDECs and colonel-level Combat Development Director from HQ TRADOC. The WTC conducts annual reviews of new and changed STOs, including the ATDs. Recommendations are forwarded to the ASTWG for approval.

The ASTWG, cochaired by the Deputy Assistant Secretary (Research and Technology) and the Assistant Deputy Chief of Staff for Programs–Force Development, is a two-star-level body with members from HQDA staff and MACOMs that have S&T oversight or development responsibility. The ASTWG approves new STOs and ATDs and any changes to existing programs. The ASTWG results are briefed to the four-star-level Army Science and Technology Advisory Group (ASTAG), cochaired by the ASA(ALT) and Vice Chief of Staff Army for annual validation of the STO/ATD portfolio.

ASTWG provides a mechanism for providing input to the Army ASTAG. The DCSCD is the ASTWG representative, and the assistant DCSCD is the technical council representative for HQ TRADOC.

C SUMMARY

The Army constantly upgrades and changes the warfighter concepts to maintain battlefield superiority over all potential adversaries and to achieve complementary capabilities with other services and nations. The S&T and requirements determination process is a holistic means to achieve material solutions to enable future joint and Army capabilities.

CHAPTER

III

ADVANCED TECHNOLOGY DEVELOPMENT (TECHNOLOGY TRANSITION)

CONTENTS

A INTRODUCTION **III–1**

B STRATEGY **III–3**

- **1 Technology Development and Transition III–3**
  - a Technology Demonstrations III–3
  - b Current Advanced Technology Demonstrations III–3
  - c Recently Completed Advanced Technology Demonstrations III–4
- **2 Manpower and Personnel Integration Program III–8**
- **3 Army Strategy for Advanced Concepts III–8**

C AVIATION **III–9**

- **1 Modernization Strategy III–10**
- **2 Systems Demonstrations III–11**
  - a Aeromechanics III–11
  - b Flight Control III–12
  - c Structures III–13
  - d Subsystems and Platform Technologies III–14
  - e Rotorcraft Drives III–21
  - f Propulsion III–21
- **3 Roadmap III–22**

D COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS **III–24**

- **1 Modernization Strategy III–24**
- **2 System Demonstrations III–25**
  - a Command and Control III–25
  - b Communications III–27
- **3 Roadmap III–32**

E INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE AND ELECTRONIC WARFARE **III–34**

- **1 Modernization Strategy III–35**
- **2 System Demonstrations III–36**
  - a Information Collection—Ground-Based Collection Systems III–36
  - b Information Collection—Airborne Collection Systems III–36
  - c Intelligence Processing and Fusion III–37
  - d Denial Systems III–38
- **3 Roadmap III–39**

F GROUND COMBAT AND TACTICAL SYSTEMS **III–41**

- **1 Modernization Strategy III–41**
- **2 System Demonstrations III–42**
  - a Systems Integration III–42
  - b Integrated Survivability III–43
  - c Mobility III–44
  - d Vehicle Electronics (Vetronics) III–45
  - e Robotic Vehicles III–47
- **3 Roadmap III–48**

G WEAPONS III–50
- 1 **Modernization Strategy** **III–50**
- 2 **System Demonstrations** **III–53**
  - a Guns III–53
  - b Missiles III–54
  - c Ordnance III–55
- 3 **Roadmap** **III–56**

H SOLDIER SYSTEMS III–58
- 1 **Modernization Strategy** **III–58**
- 2 **System Demonstrations** **III–59**
  - a Lethality III–59
  - b Survivability III–59
  - c Mobility III–60
  - d Sustainability III–61
  - e Command, Control, Communications, Computers, and Intelligence III–62
- 3 **Roadmap** **III–62**

I BIOMEDICAL III–64
- 1 **Modernization Strategy** **III–64**
- 2 **System Demonstrations** **III–67**
  - a Infectious Diseases of Military Importance III–67
  - b Medical Chemical and Biological Defense III–70
  - c Military Operational Medicine III–73
  - d Combat Casualty Care III–76
- 3 **Roadmaps** **III–78**

J CHEMICAL/BIOLOGICAL DEFENSE III–84
- 1 **Modernization Strategy** **III–85**
- 2 **System Demonstrations** **III–86**
  - a CBD—Contamination Avoidance III–86
  - b CBD—Protection III–88
  - c CBD—Decontamination III–89
  - d Smoke and Obscurants III–90
- 3 **Roadmaps** **III–91**

K AIR AND MISSILE DEFENSE III–97
- 1 **Modernization Strategy** **III–97**
- 2 **System Demonstrations** **III–98**
  - a Information Collection III–98
  - b Radar Sensors III–99
  - c Interceptors/Seekers III–99
- 3 **Roadmap** **III–100**

L ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY III–102
- 1 **Modernization Strategy** **III–102**
- 2 **System Demonstrations** **III–103**
  - a Mobility III–103
  - b Countermobility III–105
  - c Survivability III–105

d Sustainment Engineering III–106
e Topographic Engineering III–106
3 **Roadmap** **III–107**

M LOGISTICS **III–109**
1 **Modernization Strategy** **III–109**
a Combat Service/Combat Service Support Transformation Challenges III–109
b Logistics Annex of the ASTMP III–111
2 **System Demonstrations** **III–111**
a Early Entry and Resupply III–111
b Logistics Demand Reduction—Resupply III–112
c Logistics Command and Control—Situational Understanding III–113
d Logistics Demand Reduction—System Reliability III–113
e Logistics Demand Reduction—Prognostics III–114
f Logistics Demand Reduction—Power and Energy III–114
3 **Roadmap** **III–115**

N PERSONNEL PERFORMANCE **III–118**
1 **Modernization Strategy** **III–118**
2 **System Demonstrations** **III–119**
a Unit Collective Training III–119
b Simulation-Enhanced Training III–120
c Individual/Land Warfare Training III–120
d Technology Programs for Improving Personnel Performance and Leadership Development III–120
3 **Roadmap** **III–121**

O SPACE **III–122**
1 **Modernization Strategy** **III–122**
2 **System Demonstrations** **III–125**
a Command, Control, Communications, Computers, and Intelligence III–125
b Intelligence, Surveillance, and Reconnaissance and Mapping III–125
c Space Control III–126
3 **Roadmap** **III–127**

List of Figures

III–1 Attributes Envisioned for Objective Force Future Transport Rotorcraft III–9
III–2 Helicopter Active Control Technology III–13
III–3 Air/Land Enhanced Reconnaissance and Targeting III–15
III–4 Example FLIR Synthetic Scene III–16
III–5 Full-Spectrum Aviation Threat Protection III–18
III–6 Roadmap—Aviation III–23
III–7 Army's Concept for Command and Control III–25
III–8 The Concept for Networked Decisionmaking III–28
III–9 Roadmap—Command, Control, Communications, and Computers III–33
III–10 ISR Focus on the Sensor Grid III–34
III–11 Roadmap—Intelligence, Surveillance, and Reconnaissance and Electronic Warfare .. III–40
III–12 Advanced Ground Vehicle Technologies for the Mounted Force III–42
III–13 Evolving Complexity of Weapon Systems III–46
III–14 Crew Integration and Automation Testbed (CAT) ATD III–47
III–15 Roadmap—Ground Combat and Tactical Systems III–49
III–16 Multirole Armament and Ammunition ATD—Armament Development III–51
III–17 Multirole Armament and Ammunition ATD—Ammunition Suite Development III–52
III–18 Multirole Armament and Ammunition ATD—Multipurpose Warhead Development III–52
III–19 Roadmap—Weapons III–57
III–20 Roadmap—Soldier Systems III–63
III–21 Biomedical Technology: A Key Enabler of the Objective Force III–65
III–22 Genetic Vaccine Approaches III–67
III–23 Protein Structural Modeling for Development of a Staphylococcal Enterotoxin B (SEB) Vaccine III–72
III–24 Biomechanics Research III–75
III–25 Combat Casualty Care III–77
III–26 Roadmap—Biomedical: Infectious Diseases of Military Importance III–79
III–27 Roadmap—Biomedical: Medical Chemical and Biological Defense III–80
III–28 Roadmap—Biomedical: Military Operational Medicine III–81
III–29 Roadmap—Biomedical: Combat Casualty Care III–82
III–30 Anticipated Product Transitions for S&T III–83
III–31 Roadmap—Contamination Avoidance: Chemical Detection III–92
III–32 Roadmap—Contamination Avoidance: Biological Detection III–93
III–33 Roadmap—Individual and Collective Protection III–94
III–34 Roadmap—Decontamination III–95
III–35 Roadmap—Smoke and Obscurants III–96
III–36 Roadmap—Air and Missile Defense III–101
III–37 Roadmap—Engineering, Combat Construction, Mobility, and Countermobility III–108
III–38 Roadmap—Logistics III–116

III–39 Roadmap—Personnel Performance III–121
III–40 Roadmap—Space III–128

LIST OF TABLES

III–1 Ongoing Army Advanced Technology Demonstrations III–4
III–2 Completed Advanced Technology Demonstrations (FY99 and FY00) III–5
III–3 Aviation Demonstration and System Summary III–11
III–4 C^4 Demonstration and System Summary III–24
III–5 ISR & EW Demonstration and System Summary III–35
III–6 Ground Combat and Tactical Systems Demonstration and System Summary III–42
III–7 Weapons Demonstration and System Summary III–50
III–8 Soldier Systems Demonstration and System Summary III–59
III–9 Biomedical Demonstration and System Summary III–66
III–10 Chemical/Biological Defense Demonstration and System Summary III–86
III–11 Air and Missile Defense Demonstration and System Summary III–98
III–12 Engineering, Combat Construction, Mobility, and Countermobility Demonstration and System Summary III–103
III–13 Logistics Demonstration and System Summary III–111
III–14 Personnel Performance Demonstration and System Summary III–119
III–15 Space Demonstration and System Summary III–124

CHAPTER

III ADVANCED TECHNOLOGY DEVELOPMENT (TECHNOLOGY TRANSITION)

We will retain today's light force deployability while providing it the lethality and mobility for decisive outcomes that our heavy foreces currently enjoy.

—The Army Vision

A INTRODUCTION

The soldier is at the center of the Objective Force. The Army's science and technology (S&T) program is the foundation for materiel solutions to achieve the Army Vision:

- Make light forces more lethal, survivable, and tactically mobile.
- Make heavy forces more strategically deployable and agile.
- Reduce the deployed logistics footprint.

Army S&T planning efforts are focusing on areas that can enhance the Army's abilities to field a force that is more deployable, responsive, agile, versatile, lethal, survivable, and sustainable. S&T will play a vital role transforming the Army into an Objective Force that dominates across the full spectrum of operations. The investment priorities for S&T are:

- Maturing technologies for Future Combat Systems (FCS).
- Enabling Objective Force capabilities.
- Technologies designed to revolutionize lethality and survivability.
- Technologies designed to reduce logistics requirements.

Science and technology is at the heart of the Army's transformation. This chapter describes the S&T efforts that take the components and subsystems developed under the Army's 6.2 Applied Research program and demonstrate a system-level capability. System-level demonstrations for the FCS and the Objective Force begin to take shape in the Army's 6.3 Advanced Technology Development Program.

Chapter III focuses on Technology Demonstrations (TDs) and Advanced Technology Demonstrations (ATDs) that ensure the transition of innovative concepts and superior technology to acquisition programs and the Army.

This chapter is divided into 13 mission areas, aligned with the Army Modernization Strategy. Each mission area describes demonstrations ongoing within that area. Each of the mission areas is further defined with the introduction of subareas that describe specific technology efforts

within the mission area. These subareas also reflect the focus and allocation of resources within the performing laboratories and centers. The first table within each mission area lists the ATDs and TDs described within that mission area. Many of the TDs are also Science and Technology Objectives (STOs). Additional information on each STO can be found in Volume II, Annex A, of this plan.

ADVANCED TECHNOLOGY MISSION AREAS
Aviation
Command, Control, Communications, and Computers
Intelligence, Surveillance, and Reconnaissance and Electronic Warfare
Ground Combat and Tactical Systems
Weapons
Soldier Systems
Biomedical
Chemical/Biological Defense
Air and Missile Defense
Engineering, Combat Construction, Mobility, and Countermobility
Logistics
Personnel Performance
Space

B STRATEGY

1 Technology Development and Transition

The Army S&T community responded to the Army Vision and focused on a strategy vision to develop, adopt, or adapt technology and then integrate technology into operational systems.

The Army technology development programs identify and focus on selected technologies that will provide the maximum warfighting capability for every dollar invested. This demands a significant dual commitment to in-house Army applied research and to the expansion of cooperative efforts with the other services and industry. The Army leverages research and technology opportunities in academia, industry, and the international community to promote efficiency and synergy at all levels.

Key to a product-oriented strategy are the TDs, ATDs, and Advanced Concept Technology Demonstrations (ACTDs) that exploit technologies derived from applied research (6.2). These demonstrations provide the basis for new systems, system upgrades, and advanced concepts.

The Army S&T oversight process prioritizes technology needs and opportunities based on their potential to satisfy critical battlefield capability needs. The early and continuous involvement of the warfighter in the S&T capabilities definition process allows for a balanced look at the "technology push" coming from the Army's S&T community and the "requirements pull" prompted by the needs of the warfighter. This alignment is promoted by the dialog between the combat developers and materiel developers that occurs during the Science and Technology Objective (STO) reviews and the U.S. Army Training and Doctrine Command (TRADOC) S&T reviews. These S&T reviews take place in the spring and summer and result in an S&T program that is attuned to the warfighter's evolving vision of the future. The input from integrated idea teams and annual simulated future technology wargames serves to enhance the relationship between the combat and the materiel developers.

a *Technology Demonstrations*

ATDs are the highest priority efforts in the Army's technology base program, followed by STOs. However, not every worthwhile funded program can be an ATD or STO in part because the Army has chosen to reserve some program flexibility for the laboratories and centers to seize opportunities within their own organizations.

The primary focus of the TDs is on demonstrating the feasibility and practicality of a technology for solving specific military deficiencies. TDs are defined during the mature stages of the 6.2 and early 6.3 development and encourage technical competition. They are most often conducted in a laboratory or nontactical field environment. These demonstrations provide information that reduces uncertainties and subsequent engineering costs, while simultaneously providing valuable development and requirement data. Ongoing TDs are discussed under each mission area.

b *Current Advanced Technology Demonstrations*

The Army has 18 currently ongoing ATDs listed in Table III–1. ATDs are discussed in the applicable Chapter III sections as indicated on the center portion of the table. More detailed information is presented in Volume II, Annex B. STO numbers for each ATD are annotated in the third column of Table III–1, and additional information can be found in Annex A.

MANDATORY ELEMENTS THAT MUST BE ADDRESSED WHEN NOMINATING AN ATD

An approved STO

A planned program duration of no more than 3 to 5 years (in other words, a finite length rather than a continuing effort)

A planned program fully funded, largely by 6.3, and endorsed by its materiel developer

A fully developed and coordinated ATD nomination

CBTDEV and MATDEV agreement on the exit criteria, with TRADOC proponent agreement that the stated minimum performance is militarily significant

TABLE III–1. ONGOING ARMY ADVANCED TECHNOLOGY DEMONSTRATIONS

ATD	ASTMP Description Section	STO
Advanced Night Vision Goggles	III–C	III.AV.2000.01
Agile Commander	III–D	III.C4.2000.01
Air/Land Enhanced Reconnaissance and Targeting	III–C	III.AV.1996.02
Crew Integration and Automated Testbed	III–F	III.GC.1999.02
Direct-Fire Lethality	III–F	III.WP.1996.01
Enhanced Coastal Trafficability and Sea State Mitigation	III–L	III.LG.1998.02
Future Scout and Cavalry System	III–F	III.GC.1997.01
Integrated Situation Awareness and Targeting	III–C	III.AV.1998.01
Logistics Command and Control	III–M	III.LG.1999.01
Low-Cost Precision Kill 2.75-Inch Guided Rocket	III–C	III.AV.1999.03
Multifunction Staring Sensor Suite	III–F	III.GC.1997.02
Multifunctional On-the-Move Secure, Adaptive, Integrated Communications	III–D	III.C4.2000.02
Multimission/Common Module Unmanned Aerial Vehicle Sensors	III–E	III.IS.1996.01
Multirole Armament and Ammunition	III–G	III.WP.1999.01
Objective Crew-Served Weapon	III–G	III.WP.1996.02
Precision-Guided Mortar Munition	III–G	III.WP.1994.01
Robotic Follower	III–F	III.GC.2000.04
Tactical Command and Control Protect	III–D	III.C4.1997.02

c *Recently Completed Advanced Technology Demonstrations*

Six ATDs were completed in FY99 and two ATDs were completed in FY00. Table III–2 presents the results of these ATDs, addressing the product, warfighting capability, and transition of the technology. The following paragraphs summarize these completed ATDs.

ROTORCRAFT PILOT'S ASSOCIATE (RPA) ATD (1993–99). The RPA ATD program was based on a crew-centered design principle that adopts an integrated, system-wide approach to arbitrating and trading off goals and constraints for recommending a coordinated solution to the helicopter crew. RPA provides high-speed data fusion, processing, automated continuous mission planning, context-sensitive reconfiguration of mission controls and displays, efficient cockpit information management, and crew-intent estimation—all of which greatly improve situation awareness. In addition, RPA serves as the mission equipment integrator for aircrews and collects, synthesizes, and disseminates pertinent battlefield information. The ATD developed advanced data fusion algorithms, fully integrated cockpit, CDAS, and advanced MEP simulation models. Extensive knowledge engineering was performed on the rotorcraft pilots mission, and the CDAS was demonstrated in both the simulation and the actual aircraft environments.

TABLE III–2. COMPLETED ADVANCED TECHNOLOGY DEMONSTRATIONS (FY99 AND FY00)

ATD/STO No.	Product	Warfighting Capability	Supported PM/Transition Status
Rotorcraft Pilot's Associate III.D.01 [Completed FY99]	Framework for Cognitive Decision-Aid System (CDAS) to aid any entity on the battlefield, which must coordinate the actions of multiple entities Advanced data fusion algorithms Fully integrated cockpit CDAS Advanced mission equipment package (MEP) simulation models	Capability to fuse, with onboard mission processors, critical tactical information from various on- and offboard sensors in real or near real time, & the ability to provide automated mission plans to crew members that react to the fused battlefield information	Applies to all C^2, scout, & attack platforms Integration already begun in both the Air Maneuver Battle Laboratory (AMBL) & the Mounted Maneuver Battle Laboratory (MMBL) for investigation in ground & air applications & in the control of unmanned vehicles from manned platforms within the battle
Multispectral Countermeasures III.D.06 [Completed FY99]	Fiber-optic cable suitable for use on the Advanced Threat Infrared Countermeasures (ATIRCM)/Common Missile Warning System (CMWS) program Two multiline lasers for infrared countermeasures (IRCM) application Smaller jamhead that reduces the size, weight, & prime power requirements for the ATIRCM Discrete components that can be utilized as future upgrades to ATIRCM	Space weight & power savings associated with the hardware being built as preplanned product improvement (P^3I) for ATIRCM/CMWS Minijam head is 1/3 the overall size of the existing ATIRCM jamhead Reduced volume equates to 7:1 reduction in drag Changes to the ATIRCM components will reduce the overall system weight from the present 125 lb to approximately 95 lb Prime power requirements will be greatly reduced from the present 2.4 kW to 1.2 kW due to the removal of the Xenon flash lamps, which consume half the prime power to the system	Tri-service ATIRCM/CMWS improvements, integrated suite of aircraft survivability equipment (ASE), & all Army, Navy, Air Force, Special Operations Command (SOCOM)
Digital Battlefield Communications III.E.06 [Completed FY99]	Asynchronous transfer mode (ATM) insertion/adaptation of commercial technology into legacy system (mobile subscriber equipment (MSE)) Direct Broadcast Satellite (DBS), modified commercial satellite broadcast capability (video based) to meet Army needs (data based) Surrogate digital radio (SDR)—developed specification for networking data radio procurement to provide data hauler capability for the Tactical Internet (TI) Radio access point (RAP)—integrated on-the-move (OTM) network, switching capability based on commercial technologies; integrates other DBC elements to include phased-array, OTM antenna (15 Mbps OTM); airborne relay (communications payload in surrogate unmanned aerial vehicle (UAV); high-capacity trunk radio (HCTR) (15 Mbps OTM)	Changing legacy voice system to data (allows multimedia on the battlefield) Allows lower echelon commanders to have access to same data as upper echelon TI enabler Provide the basis for C^2 OTM communications to support Army warfighting doctrine via a mobile communications platform & an airborne communications node Extended range Increased area common users system data throughput and data distribution	ATM: PM–WIN–T, First Digitized Division (FDD) DBS: PM–MILSATCOM, PM–GBS, Joint Program Office (JPO) SDR: PM–TRCS, PM–NTDR, PM–JTRS, JTRS, JPO RAP: PM–WIN–T Phased array OTM antenna: PM–WIN–T Airborne relay: PEO–IEW&S, PEO–Tactical UAV Payloads HCTR: PM–WIN–T
Objective Individual Combat Weapon III.H.01 [Completed FY99]	Technologies that will demonstrate the operational utility & technological maturity of the overall OICW system design Baseline design characteristics & performance parameters will be established Information that will be available for the users to evaluate & refine their requirements, & for the PM–SA to utilize during subsequent acquisition activities	The OICW's high-explosive, air-bursting munition will be capable of defeating both exposed & defilade (hidden) targets Will provide an overmatch in system effectiveness to include an increase in standoff range by a factor of two, effective day/night operation, & significant improvements in lethality & target effects while substantially increasing the versatility & survivability of the operator The OICW's 20-mm ammunition may provide a true capability to take out multiple targets with a single round from an individual weapon	PM–Small Arms

TABLE III–2. COMPLETED ADVANCED TECHNOLOGY DEMONSTRATIONS (FY99 AND FY00) (CONT'D)

ATD/STO No.	Product	Warfighting Capability	Supported PM/Transition Status
Enhanced Fiber-Optic Guided Missile III.H.02 [Completed FY99]	300 missiles & 16 ground stations for use in demonstrations & as residual hardware for extended user evaluation	Permits positive identification & engagement of targets at extended ranges while minimizing collateral damage Connectivity allows control en route to target Gunner is protected/survivable Current concept uses a heavy HMMWV as carrier for up to 8 missiles Effective against helicopters, armor, & hard targets	Combat developers and HQDA determined this program would not continue to development
Integrated Biodetection III.K.01 [Completed FY99]	A remotely deployed Biological Aerosol Warning System (BAWS), which is a concurrent two-tiered sensor development program An automated DNA diagnostic (ADD) device that provides rapid RNA/DNA identification with significantly reduced consumables	Preexposure warning for a biological attack Order-of-magnitude increased identification sensitivity to agents while adding a first-time virus identification capability with significantly reduced logistics	Particle-counting technology in the Tier I sensors transitioned to three joint service programs: JPO–BD's Portal Shield System, the JBPDS, & the current JBREWS Program 15 Tier-2 BAWS units being fabricated for insertion into Block I JBPDS program for the man-portable & shelter JBPDS versions as replacements for the current trigger/detector systems
Battlespace Command and Control III.E.06 [Completed FY00]	A commander/staff workstation with: • Course of action (COA) development • COA analysis (COAA) • 2D/3D visualization modules	Battle planning & visualization (BPV) capability in a commander/staff workstation Refined display technology for increased situational awareness & improved tactical agility, mobility, & sustainment	Transition of COA development & analysis products to the Army's Maneuver Control System (MCS) MCS Warfighter Information Network (WIN) transitioned to PM–ATCCS Provided planning software for the En Route Mission Planning & Rehearsal System (EMPRS), a joint contingency force Army Warfighting Experiment (AWE) initiative
Mine Hunter/Killer (MH/K) III.M.09 [Completed FY00]	Prototype teleremote-operated multisensor detection system integrated with a remote-controlled, highly precise neutralization delivery system Improved detection algorithms modified to incorporate sensor fusion	Clear routes at improved rates of advance in support of survivability requirements of FCS Precision antitank mine detection & neutralization utilizing teleoperation Improved operational tempo of the route clearance mission	Neutralizer design transitioning to Ground Standoff Mine Detection System (GSTAMIDS) Block I Close-in-detector design, including fusion algorithms, are candidates for GSTAMIDS Block I

MULTISPECTRAL COUNTERMEASURES (MSCM) ATD (1997–99). The MSCM ATD demonstrated advancements in laser technology, energy transmission, and jamming techniques for an all-laser solution to infrared countermeasures. These technologies are options for P^3I to the ATIRCM/CMWS program. These MSCM improvements provide the capability of countering multicolor imaging focal plane array and nonimaging seekers. The technical concept is to use a tunable multiline laser to replace the present lamp/laser design on ATIRCM, coupled with a fiber-optic transmission line to a smaller jamhead. This new configuration will provide a 3X reduction in laser jam head volume, a 35-lb reduction in system weight, a 2X reduction in prime power consumption for the system, and a 6X improvement in jamming power.

DIGITAL BATTLEFIELD COMMUNICATIONS (DBC) ATD (1995–99). The DBC ATD integrated emerging wireless communications services and technology, including ATM, phased-array antenna (PAA), wideband data radio, personal communication system (PCS), direct broadcast video technology, aerial relay, and HCTR technologies. The three major objectives were (1) enhanced range extension, (2) OTM communications, and (3) increased Army Customer User System data throughput and improved information and data distribution. These integrated communications technologies contributed to the Task Force and Division XXI AWEs and feed into the Army FDD efforts.

OBJECTIVE INDIVIDUAL COMBAT WEAPON (OICW) ATD (1994–99). The OICW represents the next-generation infantry weapon system envisioned to replace selected versions of M16 rifles, M4 carbines, and M203 grenade launchers. The OICW is a dual-weapon system that combines the lethality of 20-mm air-bursting munitions and 5.56-mm conventional ball and tracer ammunition with a full solution fire control system to produce a leap ahead in small arms performance. The OICW ATD investigated various technologies required to design, develop, fabricate, test, and evaluate an integrated prototype system. It uses state-of-the-art technologies and provides a quantum leap over existing weapon systems. The OICW system will greatly increase user survivability and provide significant improvements in system effectiveness and operational capabilities.

ENHANCED FIBER-OPTIC GUIDED MISSILE (EFOGM) ATD (1994–99). The objective of the EFOGM ATD was to demonstrate, through virtual prototype, flight test, and integrated hardware, an EFOGM as the primary "killer" within the "hunter/standoff killer" concept of the Rapid Force Projection Initiative (RFPI) demonstration. The EFOGM system is a multipurpose, precision kill weapon system. Its primary mission is to enable a gunner in defilade to engage and defeat threat armored combat vehicles, other high-value ground targets, and hovering or moving rotary-wing aircraft that may be masked from line-of-sight (LOS) direct-fire weapon systems. EFOGM is a day, night, and adverse weather-capable system that allows the maneuver commander to extend his battlespace beyond his LOS to ranges up to 15 km. The program emphasized missile unit cost/affordability and the integrated process and product development process.

INTEGRATED BIODETECTION ATD (1996–99). The objective of the Integrated Biodetection ATD was to demonstrate two technologies: one that provides a pre-exposure warning for a biological attack, and another that provides an order-of-magnitude increased identification sensitivity to agents while adding a first-time virus identification capability with significant reduced logistics. The technologies are (1) a remotely deployed BAWS, which is a concurrent two-tiered sensor development program; and (2) an ADD device that provides rapid RNA/DNA identification with significantly reduced consumables. Three prototype generations of a lightweight, easily deployable, preexposure BAWS were successfully developed and tested.

BATTLESPACE COMMAND AND CONTROL (BC^2) ATD (1997–00). The BC^2 ATD demonstrated, through simulation and experimentation with the user, a C^2 and battlefield visualization commander and staff workstation that supports consistent battlespace understanding; forecasting, planning, and resource allocation; and integrated force management for the commander and staff. The BC^2 ATD developed and modeled the architectural basis for information transfer to and from both higher and lower echelons, including interfaces to joint and coalition forces to support worldwide, split-based military operations.

MINE HUNTER/KILLER (MH/K) ATD (1998–00). The MH/K ATD program allowed the Army to clear routes and roads through the use of robotic technology that will replace the current and dangerous traditional means of using soldiers with handheld detectors. The MH/K program developed an integrated mine detection and neutralization system. The system is intended to neutralize surface-laid and -buried, metallic and nonmetallic, antitank mines. The MH/K system consists of a multisensor, close-in detection system (metal detector, ground penetrating radar, and forward-looking infrared sensors) with a robust sensor fusion architecture and advanced aided target recognition algorithms mounted on a robotic platform. An individual mine neutralization device will be placed over the point at which a mine is detected.

2 Manpower and Personnel Integration Program

The Manpower and Personnel Integration (MANPRINT) program is a comprehensive management and technical program to improve total system (soldier, equipment, and unit) performance and reliability. This is achieved by the continuous integration of manpower, personnel, training, human engineering, system safety, health hazard, and soldier survivability considerations throughout the life cycle.

Throughout the design and development phases, MANPRINT ensures that an emphasis on soldier considerations is maintained as a high priority in system design and that system operation, deployment and employment, and maintenance requirements are matched with soldier capabilities, training, and availability. The value added of MANPRINT has been demonstrated in programs such as Comanche and Longbow Apache, where application of MANPRINT has led to significant cost avoidance and enhanced mission effectiveness. With MANPRINT, Army systems will become increasingly user-centered, reliable, and maintainable, leading to significant reductions in life-cycle costs and increased mission effectiveness.

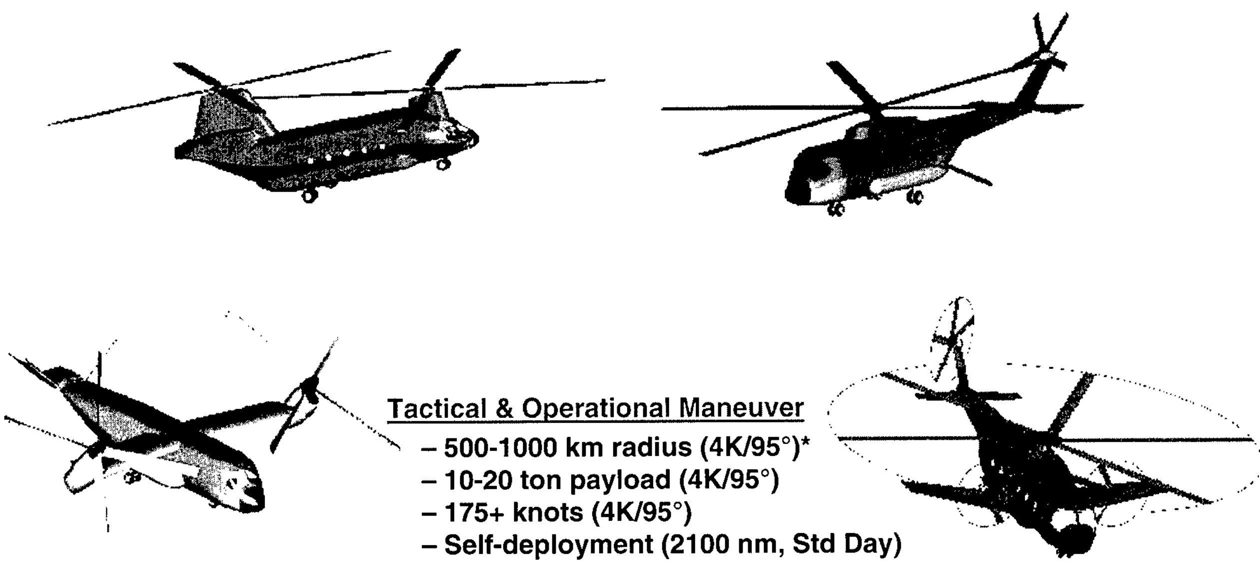
3 Army Strategy for Advanced Concepts

Advanced concepts are system concepts that are not part of current technologies employed by the military. For these, significant technical barriers remain, and questions of military worth, including tradeoffs within emerging doctrine and force structure limits, are less clear. Advanced concepts help provide the focus for the earlier stages of technology development (6.1 and 6.2 programs) and outyear projected 6.3 demonstrations. In many cases, they are conceptual in nature, and system definitions may change significantly by the time technologies and demonstrations are more fully understood. Advanced concepts represent options that are thought to be technologically achievable and useful on a future battlefield, but without a prior commitment by either the Department of the Army or the user community for development or production. Inclusion of advanced concepts in the ASTMP is based on planned or funded 6.3 programs usually in the outyears of the planning process.

C AVIATION

Army Aviation's advanced technology development (6.3) supports the DoD *Defense Technology Area Plan* technology area of Air Platforms and includes investments in the DoD subareas rotary-wing vehicle (RWV) and the Integrated High-Performance Turbine Engine Technology (IHPTET) programs.

The Army aviation S&T program will make major contributions to the Army's battle laboratory experimentation programs, the Objective Force, and the nation's rotorcraft industry (partly through participation in the National Rotorcraft Technology Center). It is postured to support the development of a Future Transport Rotorcraft (FTR) as a replacement for the CH–47 and CH–53 helicopters and potentially filling commercial and international roles. The Modular Unmanned Logistics Express (MULE), as well as other concept studies under investigation, examine the feasibility of using robotic air vehicles for cargo transport and the viability of a multirole, mission-adaptable air vehicle, harmonizing joint user requirements for next-generation rotorcraft (Figure III–1).



*Army standard "hot day:" 4,000 feet at 95°F

FIGURE III–1. ATTRIBUTES ENVISIONED FOR OBJECTIVE FORCE FUTURE TRANSPORT ROTORCRAFT

RWVs offer practical solutions to many DoD and Army operational needs, both current and future, by their ability to accomplish tasks and missions no other air or ground vehicles can perform (e.g., vertical takeoff and landing (VTOL)), operations at or below treetop level for nap-of-the-Earth (NOE) missions). The RWV configurations require significantly different analysis, integration, and design challenges from traditional fixed-wing vehicles that fly at higher altitudes. The Army's aviation S&T program, supported by NASA in three collocated activities, is the focal point for U.S. efforts in rotorcraft technology.

Rotorcraft are critically important members of the combined arms team, bringing a degree of deployability, mobility, lethality, and sustainability to the battlefield commander that is not available with other systems. With the continuing decrease in fiscal resources, affordability and dual-

use considerations for rotorcraft technologies have become increasingly important in shaping aviation strategy. Technology must support solutions to real-world problems, avoiding work that does not provide leap-ahead improvements in system capabilities. From a dual-use perspective, civil and military rotorcraft communities have a mutual stake in all but very few areas of rotorcraft technological research (e.g., survivability in battlefield environments, lethality). Improvements in handling qualities, vibration, and sound levels are equally important to civil and military rotorcraft operators.

The Army's IHPTET subarea focuses on technologies that will result in turboshaft and turboprop engines and components that are more compact, lighter weight, higher horsepower, more fuel efficient, and lower cost than those currently available. Turboshaft and turboprop technology advancements will provide enhanced mobility for the next generation of Army rotorcraft and upgrades to current systems. These systems, coupled with modern doctrine, tactics, and training, will provide U.S. soldiers with the capabilities needed to execute precision strikes, dominate maneuver battles, and project and sustain combat power. Army gas turbine propulsion technology is developed jointly and in close coordination with the other military services, NASA, and industry, thus inherently promoting dual-use technologies and processes. As a result, both civilian industry and the military industrial base are strengthened, and development is faster, more efficient, and less costly. In-house Army laboratory expertise is needed to ensure that those technologies pertinent to Army requirements are addressed, to enable the Army to be a smart buyer, and to perform the high-risk technical investigations, research, and development that ensure attainment of Army requirements. The overall cost to the taxpayer for joint ventures having both military and civil applications is therefore minimized.

In support of the Army's strategic modernization objectives, Army aviation is focusing on the development of the RAH–66 Comanche and AH–64D Apache Longbow helicopters. The armed reconnaissance Comanche will be the centerpiece of the digital battlefield, and the Apache Longbow will provide an all-weather attack capability. Battlefield commanders will quickly realize the advantages gained through the instantaneous transfer of digital reconnaissance data to the airborne shooters with their 3D maneuverability and agility to control the ever-changing battlefield tempo. As the threat proliferates and increases, the need for expanded aviation capabilities for deployability, lethality, versatility, and sustainability will continue to be critical.

1 Modernization Strategy

New and emerging technologies available to our adversaries further increase the threat. Many such technologies are intended to improve the effectiveness of air defense systems against low-flying helicopters, while other technologies strive to strengthen the protection of ground systems against attack by air. Undoubtedly, these technologies will become available on the international arms market, resulting in an even more robust capability for potential adversaries. Our own war-fighting concept and modernization requirements are predicated on the need to counter existing and emerging threats. Table III–3 presents a summary of systems, system upgrades, and advanced concepts (S/SU/AC) and demonstrations in the Army aviation S&T program supporting the transformation.

TABLE III–3. AVIATION DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Subsystems & Platform Technologies Integrated Situation Awareness & Targeting Air/Land Enhanced Reconnaissance & Targeting Advanced Night Vision Goggles Low-Cost Precision Kill 2.75-Inch Guided Rocket	**Aeromechanics** Variable Geometry Advanced Rotor Demonstration Active No-Swashplate Rotor **Flight Control** Helicopter Active Control Technology (STO) **Structures** Survivable, Affordable, Repairable Airframe Program Rotary-Wing Structures Technology (STO) **Subsystems & Platform Technologies** Advanced Rotorcraft Targeting Systems Integrated Countermeasures (STO) Image Intensification/Forward-Looking Infrared Fusion Pilotage Modernized Hellfire/Common Missile (STO) Brilliant Weapons Integration Loitering Attack Munition for Aviation Full-Spectrum Aviation Threat Protection Covert Nap-of-the-Earth Flight Fourth-Generation Cockpit Airborne Manned/Unmanned System Technology (STO)	Advanced Munitions Technology Integration Common Air/Ground Electronic Combat Suite Third-Generation Mission Equipment Package Sensor Integration Rotary-Wing Vehicle Attack/Scout Mission Equipment Package Integration Subsystem Technology for Infrared Reductions Multirole Mission-Adaptable Air Vehicle Modular Unmanned Logistics Express **Rotorcraft Drives** Rotorcraft Drive Systems for the 21st Century (STO) Small Rotorcraft Drive Technology **Propulsion** Integrated High-Performance Turbine Engine Technology Program Joint Turbine Advanced Gas Generator Phase III (STO) Future Transport Rotorcraft 15,000 Horsepower Class Engine Demonstrator Small Engine Program More Electric Rotorcraft
Advanced Concept Technology Demonstration		
Subsystems & Platform Technologies Hunter Standoff Killer Team		

System/System Upgrade/Advanced Concept	
System RAH–66 Comanche **System Upgrade** AH–64D Apache Longbow Modernization UH–60X, UH–60Q Black Hawk CH–47F Chinook	**Advanced Concept** Future Transport Rotorcraft Modular Unmanned Logistics Express Airborne Manned/Unmanned System Technology Multirole Mission-Adaptable Air Vehicle

The Army has detailed plans for equipping aviation forces well into the next century with a modern, cost-effective, warfighting fleet able to meet the challenges of low-, mid-, and high-intensity conflicts. The strategy for modernization includes:

- Complete procurement of the AH–64D Apache Longbow, complete development and procurement of the RAH–66 Comanche, and complete the CH–47 upgrades via the Improved Cargo Helicopter (CH–47F).
- Support development of advanced concepts: FTR, MULE, and airborne manned/unmanned system technology.

2 Systems Demonstrations

The six Aviation technology subareas are Aeromechanics, Flight Control, Structures, Subsystem and Platform Technologies, Rotorcraft Drives, and Propulsion. Each of these subareas is discussed below.

a *Aeromechanics*

Aeromechanics technology addresses acoustics, aerodynamic performance, rotor loads, vibration, maneuverability, and aeroelastic stability. It seeks to improve rotorcraft performance while reducing noise, vibrations, and loads.

VARIABLE GEOMETRY ADVANCED ROTOR DEMONSTRATION (VGARD) TD (2002–05). Future Army aviation activities have focused attention on technology to provide VTOL strategic and operational mobility. This mandates a 6.3 VGARD that encompasses competitive evaluation of tilt-rotor and variable diameter tilt-rotor concepts. To adequately support this demonstration, it is necessary to

undertake additional 6.2 technology development to establish the feasibility of critical subsystem components, including advanced aerodynamics, active controls, advanced actuators, hubs, and variable geometry and blade folding mechanisms. The key thrust is to identify and overcome technology and system engineering barriers in specific configurations and to establish design feasibility and affordability. This TD will demonstrate in flight an affordable leap-ahead rotor system performance for FTR requirements. From the high-risk rotor concepts developed under Advanced Rotorcraft Aeromechanics Technologies and VGART STOs, a rotor design will incorporate the affordable, fieldable characteristics of one or more of these variable geometry concepts. VGARD expands current boundaries of high-payoff variable geometry concepts for a platform that now includes helicopter and tilt-rotor operations. System predesign and critical loads will be assessed with detailed design, component fabrication, and bench tests completed next. Following ground and wind tunnel tests will be hover tests, then flight tests. The aircraft tests will include assessments of maneuverability, efficiency, and vibration. Technical benefits from combining advanced variable geometry concept attributes include a 50 percent reduction in rotorcraft vibration and a 20 percent increase in maximum blade loading. The advanced rotor concepts must be evaluated in free flight. *Supports*: All Army rotorcraft programs.

ACTIVE NO-SWASHPLATE ROTOR (ANSR) TD (2010–14). This flight demonstration of a rotor system for which high performance is enabled by primary on-blade control. The flight demonstration will be preceded by ground and wind tunnel evaluations of scaled aerocontrol elements from the Low-Cost Active Rotor program. The mixing of core concept technologies will be used to reduce vibration and increase maneuverability while allowing the flight control settings to be reached without a conventional swashplate mechanism. Savings in rotorcraft adverse forces and weight will be evaluated throughout the flight demonstration.

b *Flight Control*

Flight control technology addresses the interface between aircraft and pilot to achieve improved handling during critical mission tasks. Research looks at synthesized control laws and integrated advanced pilotage systems.

HELICOPTER ACTIVE CONTROL TECHNOLOGY (HACT) STO (1998–02). This STO will demonstrate the next-generation control system for rotorcraft and its ability to improve rotorcraft control, handling qualities, and mission effectiveness. HACT will demonstrate, through piloted simulation and flight test, the next generation rotorcraft fly-by-wire/-light digital control as a subsystem of the Vehicle Management System. System characteristics include carefree maneuvering, task tailored control laws, integration with propulsion, utility and mission subsystems required or contributing to flightpath guidance and control for Army missions. HACT will use advanced and robust control law design methods to reduce design cycle times. The goals are to demonstrate by FY02 a 50 percent increase in useable agility and maneuverability within the operational flight envelope, a 65 percent improvement in weapon system pointing accuracy, a 40 percent increase in precision maneuvering at extreme load factors, a 35 percent reduction in flight control system flight test development time (compared to 1994 technology), and a 65 percent reduction in the probability of degraded handling qualities due to flight control system failures. The program achieves RWV technology development approach (TDA) objectives for flight control, leading to improvement in maneuverability and agility, reduction in operation and support (O&S) costs, and reduction in the accident rate for new systems and system upgrades. *Supports:* Comanche, Apache, FTR, CH–47F (Figure III–2).

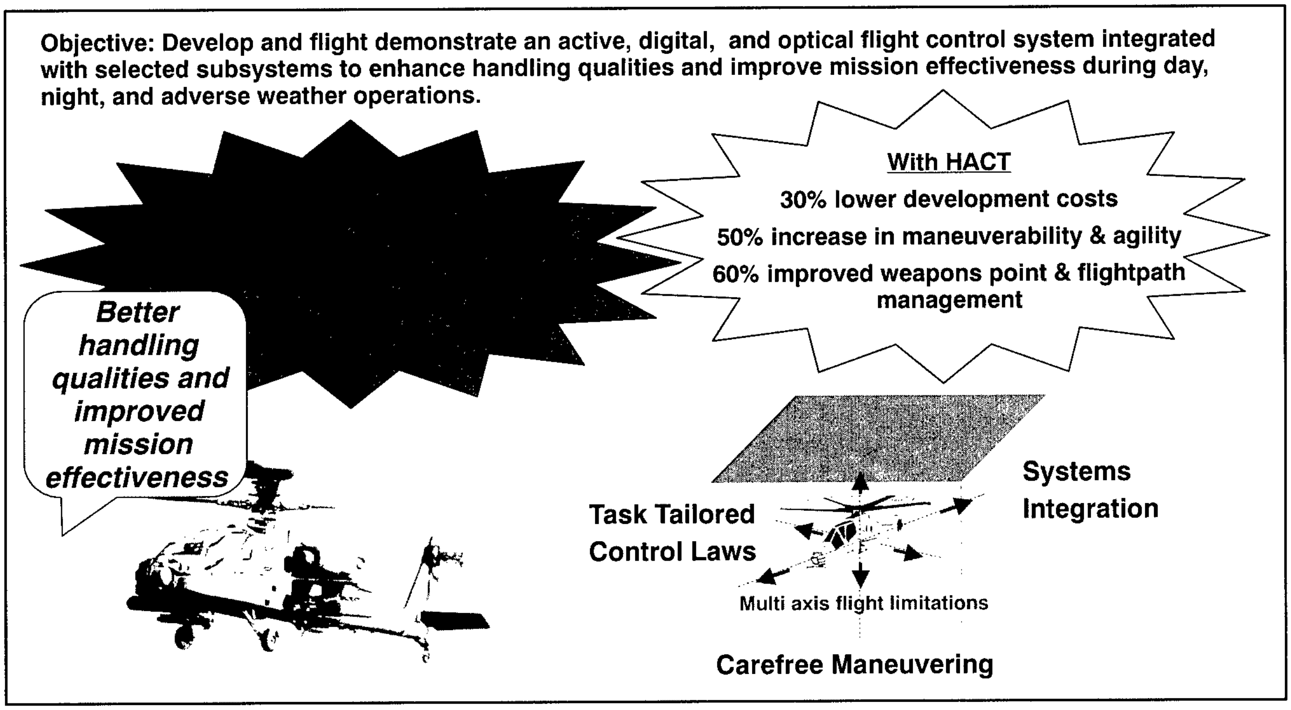


FIGURE III–2. HELICOPTER ACTIVE CONTROL TECHNOLOGY

MORE ELECTRIC ROTORCRAFT TD (2010–14). This concept effort will develop and demonstrate alternative techniques and components to current hydraulically actuated and mechanical drive systems. Advanced electromechanical/electric power generating devices will be developed and integrated to replace hydraulic/mechanical drive systems. *Supports:* Improved aircraft performance, extended range of deep attack systems, advanced propulsion.

c *Structures*

The structures subarea aims at improving aircraft structural performance while reducing both acquisition and operating costs.

SURVIVABLE, AFFORDABLE, REPAIRABLE AIRFRAME PROGRAM (SARAP) TD (2002–05). This program will demonstrate advanced airframe structures technologies for improvements in weight, development time, production cost, and maintenance cost while enabling development, procurement and fielding of medium-to-heavy (up to 50-ton) lift class RWVs that support the CSA's vision for an agile, mobile, sustainable force. It will demonstrate technology objectives supporting RWV TDA 2010 subarea goals. Rapid technology development will occur in a highly synthetic environment using virtual prototyping and the virtual factory to reduce time to market—allowing technology demonstrations to transition directly to system development and demonstration (SDD). This effort will provide technology for a 25 percent lighter, 40 percent more affordable airframe that provides ballistic tolerance and occupant safety during crash. In order to demonstrate year 2010 TDA goals necessary to support an FTR SDD, structures technology will provide continued improvements to structural efficiency, affordable producibility, and field supportability, as well as reduce development time, thus improving on the gains made with RWST. New technology development and demonstration initiatives in landing gear, fuselage, and rotors/wings will be used to achieve system-level goals necessary to support entry into the FTR SDD with acceptable risk. Advances in structural tailoring, structural integrity approaches, and crash

energy absorption systems will provide needed improvements. The described effort will leverage industry and other government agency technology developments in composites affordability, advanced metals, landing gear components, structural integrity, virtual prototyping, and modeling and simulation. By the end of FY02, complete SARAP concept analysis and initiate design phase. By the end of FY03, complete virtual prototype design and initiate developmental testing of crashworthiness, ballistic tolerance, and smart structures concepts to validate knowledge base for the FTR class airframe. By the end of FY04, build and test full-scale subassemblies to validate advanced concepts in a virtual prototype. In FY05, validate the FTR airframe structural prototype and demonstrate interface capabilities with associated rotor, drive train, and subsystem technologies. *Supports:* Primary emphasis is to provide technology options for the FTR, as well as legacy fleet upgrades.

ROTARY-WING STRUCTURES TECHNOLOGY (RWST) STO (1997–01). Advanced structural concepts that are highly tailored for structural efficiency, are inspectable and supportable, provide enhanced ballistic tolerance and crashworthiness, and are designed for affordability will be demonstrated. Rapid concept selection and evaluation techniques, such as knowledge-based expert systems, cost and structural analyses, and 3D solid modeling and simulations, will be used to optimize a military rotorcraft airframe configuration for maintainability, sustainability, and supportability. Design optimization, validation, and manufacturability analysis will be accomplished during an extended preliminary design phase using structural and manufacturing simulation validated with significant coupon and element testing for risk mitigation. *Supports*: Primary emphasis provides technology options to the UH–60, AH–64, Improved Cargo Helicopter (CH–47F), RAH–66 and SOA upgrades, future air vehicles (FTR), collaborative technology. Contributes to RWV TDA technology efforts and objectives (structures, subsystems), goals, and payoffs.

d *Subsystems and Platform Technologies*

The subsystems and platform subarea addresses a broad range of S&T topics related to support, sustainment, and survivability, and to the application of high-performance weapons on rotorcraft.

INTEGRATED SITUATION AWARENESS AND TARGETING (ISAT) ATD (1999–02). Army air and ground platforms lack integrated passive threat updates. With the unambiguous recognition of hostile intent, it will be possible to combine and coordinate the defense of the platform in a more effective and efficient manner. Information collected by the onboard sensors will be provided to other consumers providing the warfighter with an immediate localized battlespace awareness as well as an indigenous means to update their order of battle while on the move. The ISAT ATD will demonstrate a fully integrated multispectral airborne "system-of-systems" threat warning suite. The technologies and concepts demonstrated will include advanced RF/IR/EO detectors and receivers capable of precise angle-of-arrival measurements, advanced signal processing, multisensor data fusion techniques, tactical electronic warfare decision aids, and connectivity to network-centric entities in the tactical-level battlespace. The payoff for the warfighter is an increased awareness of the battlespace that will reduce search volume for reduced time to target, assist with combat ID reducing fratricide, and provide for optimum execution of tactics vs. developing scenario from platform to upper echelons all while on the move. Transition will be through form–fit–improved function modules for the AN/AVR–2A, Suite of Integrated IR Countermeasures AN/ALQ–212/AAR–57, and the Suite of Integrated RF Countermeasures AN/ALQ–211.

ADVANCED ROTORCRAFT TARGETING SYSTEMS (ARTS) TD (2005–06). This program integrates new targeting sensors and target trackers to provide longer-range acquisition and identification and an enhanced engagement capability in high clutter environments. Applicable to all helicopter missions, this effort aids in alleviating deficiencies in performance against evolving threats. The initial approach will integrate and test commercial-off-the-shelf and tri-service horizontal technology integration (HTI) solutions for current deficiencies. These systems will include color television, advanced forward-looking infrared (FLIR) sensors, and improved target trackers. Closed-loop fire control capabilities will be investigated that provide improved probability of hit for dynamic engagements. Mid-program efforts will integrate and test emerging next-generation sensor technologies (multispectral quantum well sensors with integral laser range finding and target profiling, passive millimeter wave imaging for all-weather targeting and urban warfare peculiar applications, or distributed sensors for 360-degree situational awareness). Ocular tracking will also be explored for improved cueing.

INTEGRATED COUNTERMEASURES (ICM) STO (1999–04). This program will develop and demonstrate a leap-ahead integrated RF, EO, IR countermeasures system upgrade for the AN/ALQ–211 and –212 systems for both conventional and reduced signature aircraft with HTI-to-ground survivability. This program will counter such future threats as multispectral RF, IR missile seekers, and air defense systems using integrated radar, laser, and FLIR target acquisition and tracking, to include special reduced detection jamming nodes for reduced signature platforms. This integrated approach will permit a multispectral countermeasures attack on enemy weapon systems during their acquisition, tracking, and homing phases, to include jamming of proximity fusing. In addition, this program has been revised to include the development and demonstration of a two-color, mid-IR threat warning system and a second-generation, directed-missile countermeasure device for ground vehicles in support of FCS with HTI to air vehicles. This program will help counter ATGMs, KE and HEAT rounds, rocket-propelled grenades and top-attack munitions. *Supports:* Upgrades to the AN/ALQ–211 and –212, ICM effort, ISAT, CAGES, FCS and Vehicular Integrated Defense System.

AIR/LAND ENHANCED RECONNAISSANCE AND TARGETING (ALERT) ATD (1997–01). This ATD will demonstrate automatic target acquisition and enhanced target identification via a second-generation FLIR/multifunction laser sensor suite for rapid wide-area surveillance and targeting. ALERT will leverage ongoing Air Force and DARPA developments for search on-the-move (OTM) automatic target recognition. Second-generation FLIR and multifunction laser data will be fused to allow large search areas to be covered with high targeting accuracy while at low depression angles and high platform motion. Range profiling of the highest priority targets will provide target identification. *Supports:* Comanche, Apache improvements (Figure III–3).

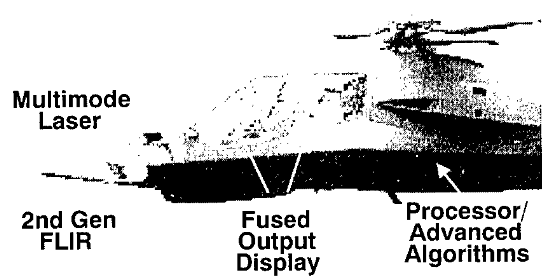


FIGURE III–3. AIR/LAND ENHANCED RECONNAISSANCE AND TARGETING

ADVANCED NIGHT VISION GOGGLES (ANVG) ATD (2000–03). This ATD will address current pilotage goggle system limitations of 40-degree field of view (FOV), weight, and interoperability. The improved system will be HTI for all Army applications and provide IR fusion for dismounted forces. This will result in improved situational awareness and safer pilotage with wider FOV and improved resolution. This system will also enhance operations in urban terrain with low-/high-

altitude observatory capability and added IR target detection capability for dismounted soldier. *Supports:* PM Comanche, Director of Combat Development (DCD) Aviation Center, AMBL, MBBL, DBBL.

IMAGE INTENSIFICATION (I^2)/FORWARD-LOOKING INFRARED (FLIR) FUSION PILOTAGE TD (2002–05). This TD will demonstrate image fusion upgrades to the baseline Comanche dual-spectrum (I^2/FLIR) pilotage system to increase mission effectiveness and survivability for future high-performance rotorcraft. Knowledge-based image fusion algorithms will significantly enhance image resolution and will support concurrent demonstration of aided NOE pilotage technology. *Supports:* Future Comanche/Apache upgrades and advanced concepts (Figure III–4).

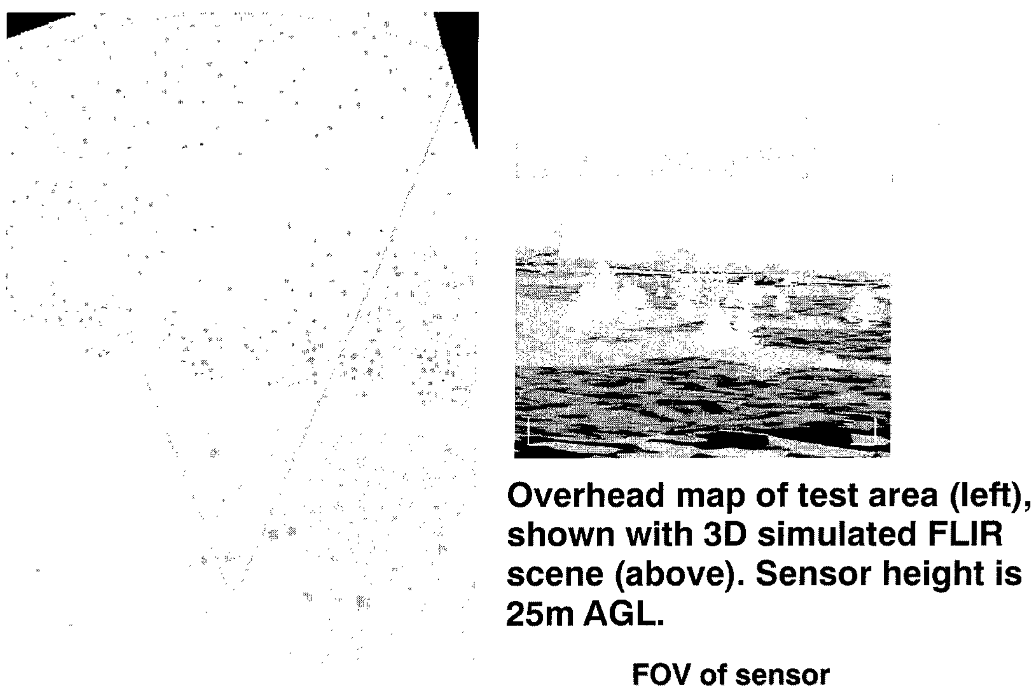


FIGURE III–4. EXAMPLE FLIR SYNTHETIC SCENE

MODERNIZED HELLFIRE/COMMON MISSILE (MODHF/CM) STO (1999–03). This effort will address seeker and propulsion technologies incorporating multimode applications (i.e., ground-to-ground missions in support of Common Missile as well as the traditional Hellfire/Longbow air-to-ground missions). The ModHF program will leverage missile technology being developed in support of the NetFires effort and supports the Army vision of lighter, more lethal weapon systems contained on the FCS and Common Missile. The development of the technologies in this program and associated system integration efforts are part of a joint AMRDEC/PEO Tactical Missile ModHF/CM program designed to achieve a Milestone B decision based on the new acquisition methodology, simulation-based acquisition. *Supports:* Hellfire, NetFires, Common Missile, RAH–66 Comanche, AH–64D Apache.

LOW-COST PRECISION KILL (LCPK) 2.75-INCH GUIDED ROCKET ATD (1999–03). This ATD will demonstrate a low-cost (<$10,000), accurate (1-m circular error probable (CEP)) 2.75-inch guided rocket providing a standoff range of 6 km and a surgical strike capability against specified soft point targets. Using a small strapdown laser seeker, off-the-shelf inertial devices, and a low-cost control mech-

anism, a high single-shot P_k will be achieved, reducing cost/kill by 2–4X, minimizing collateral damage, and increasing the number of stowed kills by 4–20X. *Supports:* AH–64D Apache, RAH–66 Comanche, Kiowa Warrior OH–58D, SOF, Navy/Marine Corps AH–1W.

BRILLIANT WEAPONS INTEGRATION (BWI) TD (2004–08). This TD will integrate and demonstrate, through simulation and ground and flight tests, future combined arms interoperable advanced aviation weapons, target acquisition and fire control technologies, and aviation platforms and will quantify resulting increases in aviation mission effectiveness. Full-spectrum lethality will be demonstrated from less-than-lethal to conventional lethal-kill mechanisms. *Supports:* Apache, Comanche, future systems.

LOITERING ATTACK MUNITION—AVIATION (LAM–A) STO (2000–02). This effort will demonstrate, through flight simulations and component developments, technologies for long-range weapon systems for airborne forces that will provide enhanced sensor–shooter connectivity, continuous in-flight autonomous feedback of target coordinates to local field commanders, minimized timelines for placing weapons on target, and battlefield damage assessment with last images before impact as well as demonstrate automatic and man-in-the-loop target acquisition and engagement concepts. This effort will also provide a rail interface and boost motor design capable of achieving stable helicopter rail launch in the presence of rotor downwash. Supports: Beyond Line-of-Sight Networked Fires.

FULL-SPECTRUM AVIATION THREAT PROTECTION (FSATP) TD (2002–05). This TD demonstrates balanced integration of rotorcraft survivability for the most effective combinations of active countermeasures (CM) and susceptibility reduction features for full-spectrum threats (i.e., radar, acoustics, IR, and visual). It will demonstrate survivability against advanced threat sensors, smart weapons, and munitions. The survivability codes will be validated and verified by installing equipment on aircraft with known signatures and flight testing against various threats. Enhanced survivability and system performance features for aircraft will be tailored for specific warfighting situations by minimizing weight and aerodynamic impact while maintaining low-observable cross section, minimizing threat detection of active CM, increasing jammer effectiveness, optimizing mission routes and tactics, and reducing production costs. By FY05, the TD will demonstrate on a fielded AH–64 Apache helicopter the synergistic benefits that can be obtained by integrating state-of-the-art technologies related to advanced active electronic warfare and decoy CM, advanced passive signature reduction technology, and advanced aircrew situational awareness and tactics. The program will capitalize on existing and in-process technical developments while identifying and pursuing advanced technologies necessary to support areas where advanced threat development is expected to surpass current capabilities. The primary challenge for this program is to integrate active and passive CM that can produce a mission-effective, survivable rotary-wing vehicle that is both supportable and affordable. By FY02, the program will select current and state-of-the-art active and passive CM and aircrew situational awareness concepts, and develop preliminary system designs. By FY03, hardware will be fabricated, and initial software will be developed. By FY04, a hot bench integration and subsystem flight test will be performed. By FY05, a system flight test and simulation validation demonstration will be performed. The FSATP program will integrate passive features such as innovative IR suppressors, multispectral paints and coatings, lightweight insulative materials, advanced camouflage, and low-glint canopy coatings along with current and developmental IR and RF jammers and decoy systems. In addition, advanced in-cockpit situational awareness systems, such as the Rotorcraft Pilot's Associate (RPA) and the ISAT systems will be incorporated. These technologies will support achievement of the rotary-wing 2005 TDA technology goals of a 50 percent reduction in aircraft IR/

visual/EO signatures. In turn, these will contribute to a 50 percent increase in active aircraft survivability equipment effectivenesss. Together, a 50 percent increase in probability of survival will be demonstrated (Figure III–5). *Supports:* Aviation systems, Project Reliance, multiservice applications.

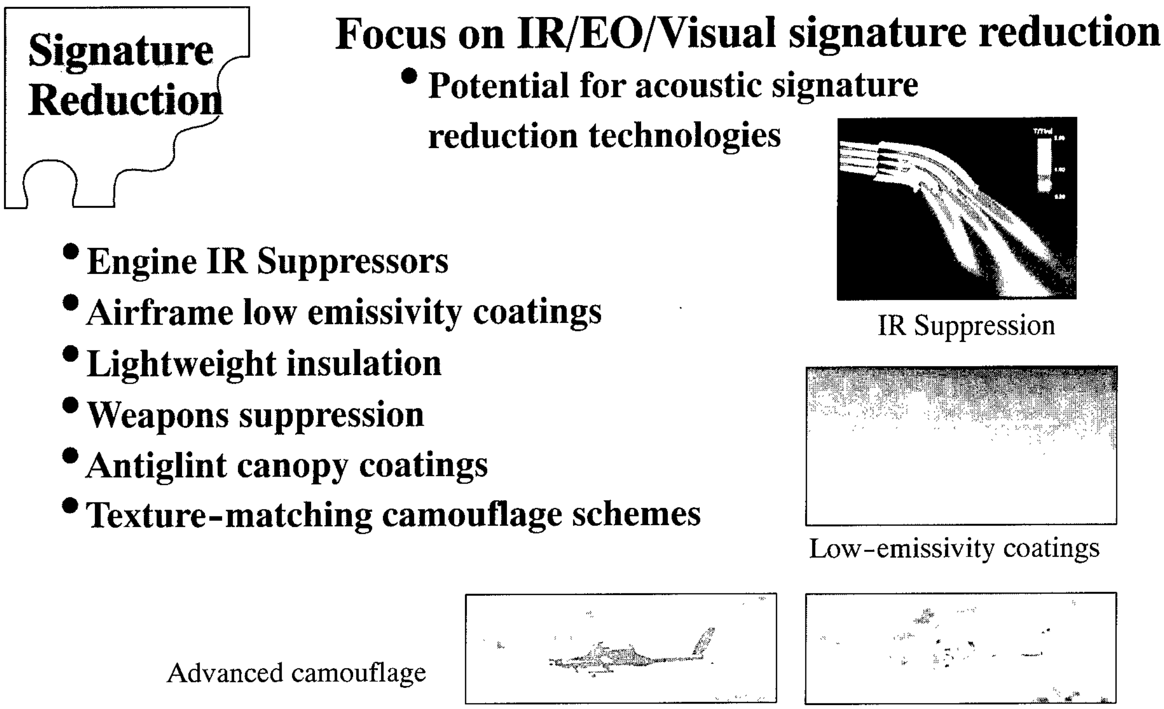


FIGURE III–5. FULL-SPECTRUM AVIATION THREAT PROTECTION

COVERT NAP-OF-THE-EARTH (NOE) FLIGHT TD (2004–06). This TD will demonstrate an advanced, effective, and highly integrated rotorcraft pilotage system to operate covertly NOE and unobtrusively in urban areas with increased survival in hazardous flight environments or emergency situations with reduced crew workload during day, night, and adverse weather. Reduced crew workload, aided precision flightpath control, and increased safety will enable crew members to focus on mission-level functions while maintaining full vehicle and flightpath control. The TD will demonstrate a comprehensive air vehicle management system for pilotage; a large-scale integrated mission equipment suite; automated protection from obstacles, terrain, and other in-flight hazards; increased capability for rotorcraft operations that both avoid and use obstacles, terrain, and threats for military operations; and increased safety for military and commercial rotorcraft operating in hazardous flight environments. *Supports:* FTR, CH–47F, Apache Longbow, far-term manned and unmanned rotorcraft.

FOURTH-GENERATION COCKPIT TD (2004–08). This TD will demonstrate the next generation of air vehicle cockpits. The effort will develop and incorporate advanced displays for full glass cockpit; 3D display technology; selectable touch, cyclic grip cursor, or pupil-tracked cursor information access capability; rapid pilot-reconfigurable information layout on displays; automated artificial intelligence (AI) "advisor" aiding; intelligent, adaptive interfaces; advanced selectable "windowless" cockpit synthetic vision systems; advanced information display symbology; and advanced flight control designs. Displays, AI, and cockpit technology from Air Force, Navy, and NASA programs will be incorporated into system design. The TD will demonstrate increased pilot per-

formance and overall mission and reduced pilot susceptibility to injury by laser, directed energy, or other sources in hostile electromagnetic environments. *Supports:* FTR, CH–47F, Apache Longbow, multirole, mission-adaptable air vehicle (MRMAAV), advanced ground vehicle cockpits.

AIRBORNE MANNED/UNMANNED SYSTEM TECHNOLOGY DEMONSTRATION (AMUST) STO (2000–03). AMUST will demonstrate through simulation and flight test the control mechanisms, intelligent linkages, and integration architectures to allow a manned air vehicle (MAV)/unmanned aerial vehicle (UAV) system to operate as an effective warfighting system-of-systems to increase the combined arms team's battlefield effectiveness. This TD will allow a 25 percent increase in operational efficiency, a 35 percent increase in operational effectiveness against tactical and short dwell (i.e., perishable targets), a 50 percent reduction in hunter-to-shooter timelines, and a 25 percent increase in survivability of the manned system. The goal of the AMUST program is to maximize the effectiveness and efficiencies of MAV and UAV systems operating as teams and demonstrating their ability to support the maneuver commander's requirements across the full spectrum of conflict. This program will focus on increased efficiency and effectiveness of the reconnaissance and attack helicopter forces, while concurrently improving their lethality and survivability and significantly reducing fratricidal incidents. Crucial to AMUST is the integration and demonstration of technologies that will enable manned systems to operate and use UAVs, without detracting from the manned system's tasks, through an intelligent autonomous system. The RPA program results will provide valuable information to the AMUST program through the application of real-time cognitive decision-aiding technology. The intelligence architecture and autonomy algorithms from RPA can be applied to the AMUST program, and AMUST will be used to address the Comanche operational requirements document for future requirements to conduct reconnaissance missions using the complementary capabilities provided by UAVs. Also, AMUST will demonstrate that technologies can be horizontally integrated into ground maneuver reconnaissance and attack teams using unmanned ground vehicles to provide many of the same advantages realized by the air maneuver teams. *Supports:* AMBL, Aviation Battle Command, Mounted Maneuver, Extended Ranges of Deep Attack Systems, Rapidly Deployable Attack Systems.

ADVANCED MUNITIONS TECHNOLOGY INTEGRATION (AMTI) (2005–07). This program will integrate future combined arms interoperable, advanced aviation weapons and fire control technologies with manned and unmanned aviation platforms, and quantify resulting increases in aviation mission effectiveness. These new and emerging weapon systems will result in improved standoff, greater lethality and additional, enhanced mission capabilities. Current HTI candidates include RF Hellfire integration on platforms without fire control radars, suppression of enemy air defense systems (Sidearm, Antiradiation Hellfire), air-to-air missiles with required target acquisition and fire control enhancements, Modernized Hellfire/Common Module Missile, and Precision Kill Autonomous Targeting Missile. Advanced 2.75-inch rockets (with improved fuzing, smart launcher, higher velocity, longer range, improved accuracy, enhanced warheads) will also be integrated as the system emerges from development. *Supports:* DCD Aviation Center, AMBL, D&SABL, AH–64D Apache, RAH–66 Comanche, Kiowa Warrior OH–58D, SOF, Navy/Marine Corps AH–1W.

COMMON AIR/GROUND ELECTRONIC COMBAT SUITE (CAGES) TD (2005–09). Ground vehicles and aviation platforms flying at the NOE face similar threats. This effort will capitalize on that similarity to develop sensors and CM hardware common to both types of platforms. The capabilities provided by this effort will enhance the platform's survivability against future highly integrated and multirole air and ground attack weapons with multispectral sonic, RF, IR, EO, and homing sensors. These capabilities will also enhance combat effectiveness by improving precision target-

ing, situation awareness, and real-time bidirectional C^3I feeds. This effort will develop a family of modular sensors for RF/EO/IR signal analysis and integrate those using "plug-and-play" configuration into different multispectral systems tailored to the different platforms and missions. It will use digital systems to generate the countermeasure waveforms for IR and RF countermeasures. FCS platforms and missions will be the primary candidates considered for this effort. Also, low-observable platforms will be addressed through low cross section sensors and specifically tailored countermeasures to deceive and reduce detection by remote sensors.

THIRD-GENERATION MISSION EQUIPMENT PACKAGE (MEP) SENSOR INTEGRATION TD (2009–11). This concept demonstration will demonstrate an advanced integrated sensor suite capable of multiple target track and search while OTM and simultaneously provide improved pilotage and aircraft survivability equipment capability. It will integrate and demonstrate advanced multispectral imaging, large focal plane sensor suite, and MMW and laser devices for pilotage, target acquisitions, and threat detection. It will provide a distributed sensor arrangement to allow spherical coverage without turrets and other pointing devices, and incorporate an architecture that centrally processes and fuses sensor information for optimum presentation. *Supports:* Enhanced Apache, Improved Comanche, FTR, future manned and unmanned programs.

ROTARY-WING VEHICLE (RWV) ATTACK/SCOUT MISSION EQUIPMENT PACKAGE (MEP) INTEGRATION TD (2011–13). This concept will integrate and demonstrate a synergistic combination of advanced technologies to produce an overwhelming upgrade capability to the attack and scout/attack rotorcraft fleet. Technologies to be leveraged include automated target acquisition integration, advanced multirole gun system, integration of brilliant missiles, advanced full-spectrum threat protection, covert NOE pilotage with I^2/FLIR fusion, fourth-generation cockpit and displays, aircraft system self-healing, advanced low-cost digital avionics, and advanced integrated teaming with UAVs. *Supports:* Current and future rotorcraft.

MULTIROLE MISSION ADAPTABLE AIR VEHICLE (MRMAAV) TD (2009–13). The MRMAAV concept will demonstrate the feasibility of using a common airframe and powerplant(s) to conduct multiple primary mission roles with the same aircraft with minimal impact on equipment interchanges (e.g., avionics, weapons, survivability packages). Common dynamics and aeromechanics components would be incorporated to support development of manned and unmanned systems. The MRMAAV concept offers battlefield commanders unprecedented mission flexibility to reconfigure aircraft in the field for various mission roles. Fewer numbers of aircraft and crews will be required to perform multiple missions. *Supports*: Far-term advanced concepts.

MODULAR UNMANNED LOGISTICS EXPRESS (MULE) TD (2009–11). This concept program will develop and flight demonstrate a UAV configuration that supports automated logistics movement of modular payloads up to 10,000 lb. The aircraft will be VTOL, self-deployable, and capable of all-weather operations. *Supports*: Aircraft inter- and intratheater capability.

HUNTER STANDOFF KILLER TEAM (HSKT) ACTD (2001–06). The primary objectives of the HSKT concept are to team manned platforms with UAVs and provide a cognitive decision aid system onboard the Joint Task Force (JTF) Army Airborne Command and Control System (A^2C^2S). This will result in an increased identification/standoff distance for manned systems and extended weapons delivery range from them, airborne manned and unmanned

HSKT ISSUES

- **No airborne sensor-to-airborne-shooter link**
- **Inability of maneuver commander to manage coalition assets on the move**
- **Communication between sensor and shooters too slow**
- **High-altitude UAV has high false target rate (80 percent) and no linkage to airborne shooters**
- **Highly lethal and prolific integrated air defense weapons**
- **Shooter must move too close to identify targets**

sensor-to-shooter linkage with fast communications, direct UAV targeting information to shooters and commander's staff, and staff level 4 control (sensor payload and flight navigation) of the UAV. The JTF commander will thus have tools to make faster, better tactical decisions, thereby enhancing his and his staff's ability to track all entities, monitor team status, be alerted to changing situations, develop optimum courses of action, and manage and fuse intelligence data.

e *Rotorcraft Drives*

Rotorcraft drives technology addresses prime power transmission systems and components that are more compact, lighter weight, higher horsepower, more efficient, and less costly than current systems.

ROTORCRAFT DRIVE SYSTEMS FOR THE 21ST CENTURY (RDS–21) STO (2001–05). The RDS–21 STO will demonstrate a major advance in rotorcraft power transmission technology through the application of emerging technologies in materials, structures, mechanical components, dynamics, acoustics, lubrication, and manufacturing processes. In terms of warfighting capabilities and payoffs, RDS–21 technology will provide a 20–30 percent increase in range or payload from the current rotorcraft baseline, and significantly improve readiness, maneuverability, agility, and O&S cost. It will develop and demonstrate advanced mechanical power transmission technology, supporting legacy and future large systems, such as the FTR, that require affordable, breakthrough levels of performance. RDS–21 will demonstrate the Phase II RWV TDA goals by demonstrating a 35 percent increase in drive systems power-to-weight ratio, 25 percent decrease in drive system O&S cost ($/fh), 25 percent reduction in drive system production cost ($/hp), and 15-dB reduction in transmission-generated noise. The improvements resulting from this program are aligned with the CSA's vision and will provide the U.S. military with rotorcraft that can better sustain the momentum of forward deployed forces, have increased lethality and firepower, and are more survivable and sustainable in the increasingly hostile environments expected in future conflicts. *Supports*: FTR, current fielded rotorcraft and future upgrades.

SMALL ROTORCRAFT DRIVE TECHNOLOGY TD (2005–07). This program will provide component and system-level technology improvements for small turboengines and drive systems (3,000 hp and lower) that will enable an extension of the 75 percent reduction in battlefield fuel requirement to small propulsion systems. These technology advances must be developed to enable demonstrators planned for small rotorcraft and VTOL UAVs. It will develop and validate special material, aerodynamic, thermodynamic, and manufacturing issues that are unique to small engines. Small engine technology challenges include proportionally higher secondary flow losses, difficulties in cooling turbine components, proportionally larger real estate claims by mechanical and ancillary components, and extensive use of nonaxial turbomachinery with attendant unique aerodynamic and structural considerations. These technologies will support engine demonstrations planned for the 2009–2012 and 2013–2016 timeframes. Smaller engines are anticipated to operate at higher power output shaft rotational speeds, and higher speed reductions will be required than are in current and planned drive systems. In addition, the very small packages are expected to benefit from new arrangements of components and totally new power transfer schemes. Advances in drive system arrangements, components, concepts, and material and lubrication systems will be applied to lightweight reliable power transmission systems for future rotorcraft.

f *Propulsion*

This subarea addresses engine component and system technologies for small gas turbines (turboshaft and turboprop) to reduce fuel consumption while increasing power output.

INTEGRATED HIGH-PERFORMANCE TURBINE ENGINE TECHNOLOGY (IHPTET) (JOINT TURBINE ADVANCED GAS GENERATOR (JTAGG) PHASE III) STO (1999–03). The JTAGG program is a tri-service effort structured to be compatible with the goals of the IHPTET initiative. A full engine demonstration of the improvements in gas turbine technology resulting from the JTAGG program will be conducted as required to be compatible with S/SU/AC requirements. Results will be improvements in performance, efficiency, and power-to-weight ratio over current production engines. The demonstration will incorporate advanced materials and materials processing, modeling and simulation, computational fluid dynamics, and manufacturing science. This effort is Phase 3 of the JTAGG program and will demonstrate the performance goals corresponding to the overall IHPTET goal of doubling turbine engine propulsion capability by the year 2003. The Phase 3 goals include a 40 percent reduction in specific fuel consumption (SFC), a 120 percent increase in horsepower-to-weight ratio, and a 35 percent reduction in production and maintenance cost. This program is planned to involve demonstrations in the 10–30-lb/s flow range. This program will provide significant increases in range and payload capabilities while significantly reducing the logistics burden on the battlefield. *Supports:* All rotorcraft programs.

FUTURE TRANSPORT ROTORCRAFT (FTR) 15,000 HORSEPOWER CLASS ENGINE DEMONSTRATOR TD (2004–07). This effort will provide full engine demonstration of a gas turbine engine in the 15,000-hp size class. Program goals will include a 35–40 percent reduction in SFC, a 100–120 percent increase in power-to-weight, and a 35 percent reduction in O&S cost. Potential applications for this large turboshaft engine technology include FTR and upgrades of legacy systems. This advanced propulsion development provides needed self-deployable, range and payload operational capabilities with a reduced logistics footprint in support of the Army vision of a full-spectrum force.

SMALL ENGINE PROGRAM TD (2008–14). This concept effort is a versatile and affordable small engine demonstrator that will provide advanced gas turbine engine technology for applications requiring 3,000-Shp or less. Program objectives will be focused on reducing SFC, increasing horsepower-to-weight ratio, and reducing development, production, and maintenance costs for small-core flow engines. This propulsion technology will be applicable to legacy systems such as enhanced T800 for Comanche or future inhabited or uninhabited systems. The effort will use smart controls and active component control technologies to demonstrate an ultra-intelligent engine that can achieve improved performance while optimizing component life through advanced diagnostics and prognostics capabilities. Also, this technology provides needed self-deployable, range and payload operational capabilities with reduced logistics footprint in support of the Army vision of a full-spectrum force.

3 Roadmap

The roadmap for Aviation (Figure III–6) portrays the Army's use of TDs and ATDs to support the development of its future aviation systems, and provide dual-use technology for the nation's rotorcraft industry. Programs are separated by platform vs. mission equipment technologies. Many of these demonstrations are designed to establish a proof of principle (i.e., to serve as a testbed, validate feasibility, and reduce cost and risk in the SDD phase). The roadmaps reflect two technology insertion windows offering opportunities for technology application to aircraft S/SU/ACs. Technology insertions that may occur through material change programs for fielded systems, such as AH–64D Apache, UH–60 Blackhawk, CH–47 Chinook, OH–58D Kiowa Warrior and Special Operations Aircraft, are not shown.

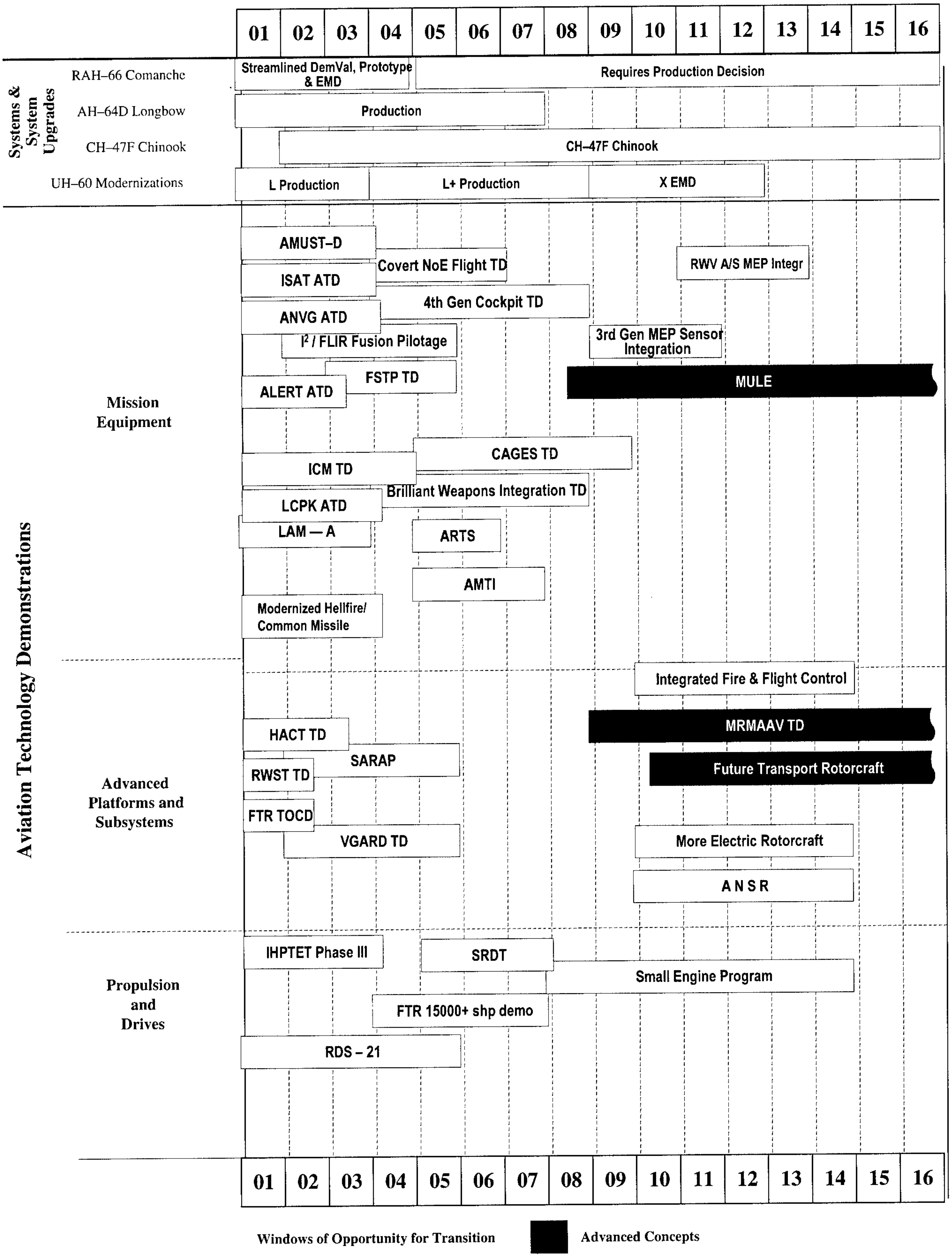


FIGURE III-6. ROADMAP—AVIATION

D COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS

Command, control, communications, and computers (C^4) is the Army's force multiplier for the digitized battlefield of the 21st century. C^4 is synonymous with information superiority as defined by the Chairman, Joint Chiefs of Staff in *Joint Vision 2010* as "the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same." Command and control (C^2) is the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. The C^2 process involves gathering information, assessing the situation, identifying objectives, developing alternative courses of action (COAs), deciding on a COA, transmitting orders that can be understood by recipients, and monitoring execution. This requires maintaining a seamless, robust communications and computer network linking all friendly and multinational forces and providing common awareness of the current situation.

1 Modernization Strategy

The Army's intent is to make heavy forces more strategically responsive and light forces more lethal and survivable. As stated in the *Army Vision:* "We will provide the nation an array of deployable, agile, versatile, lethal, survivable, and sustainable formations, which are affordable and capable of reversing the condition of human suffering and resolving conflicts decisively." The highest priority S&T initiatives enabling the new vision are the Future Combat Systems (FCS) and Objective Brigade Combat Team (BCT) initiatives. The FCS will be a fighting ensemble of capabilities that meets the weight constraints for C–130 transportability. The goal is to create combat capabilities that can enter production and be fielded as early as 2010. A robust communications infrastructure, reliable C^2 capabilities, and information assurance coupled with computer technology comprise the foundation of any and all Army C^4 modernization in support of the FCS concept. Table III–4 lists the Army's C^4 advanced technology (6.3) programs.

TABLE III–4. C^4 DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Command & Control Logistics Command & Control Agile Commander **Communications—Mobile Networking** Multifunctional On-the-Move Secure, Adaptive, Integrated Communications **Communications—Information Assurance** Tactical Command & Control Protect	**Command & Control** Battlespace Tactical Navigation (STO) Collaboration Technology for the Warfighter Command & Control for Joint Intelligence, Surveillance, & Reconnaissance (STO) E-Sustainment Warrior/Platform Command & Control **Communications—Mobile Networking** Army Communications Integration & Cosite Mitigation (STO) Network Management Assistant Army.com **Communications—Unattended Sensor Networking** Smart Sensor Communications Networks	**Communications—Information Assurance** Tactical Information Assurance Technology **Communications—Antennas** Antennas for Communications Across the Spectrum (STO) Advanced Antennas (STO) **Communications—Secure Personal Communications** Dismounted Warrior Command, Control, Communications, Computers, & Intelligence Technologies Universal Handset **Communications—Reachback** On-the-Move Tactical Satellite Communications (STO) Next-Generation Satellite Communications
Advanced Concept Technology Demonstration		
Command & Control Rapid Terrain Visualization Theater Precision Strike Operations		

2 System Demonstrations

The two C^4 technology subareas are Command and Control and Communications.

a *Command and Control*

C^2 is the exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of the mission. A primary component of effective C^2 is battlefield visualization resulting in a plan, prepare, and execute cycle. Incorporating a more digitized C^2 capability will allow the Army to change from a staff-centered and planning-focused force to one that is commander-centered and execution-focused. Figure III–7 represents the Army's concept for command and control.

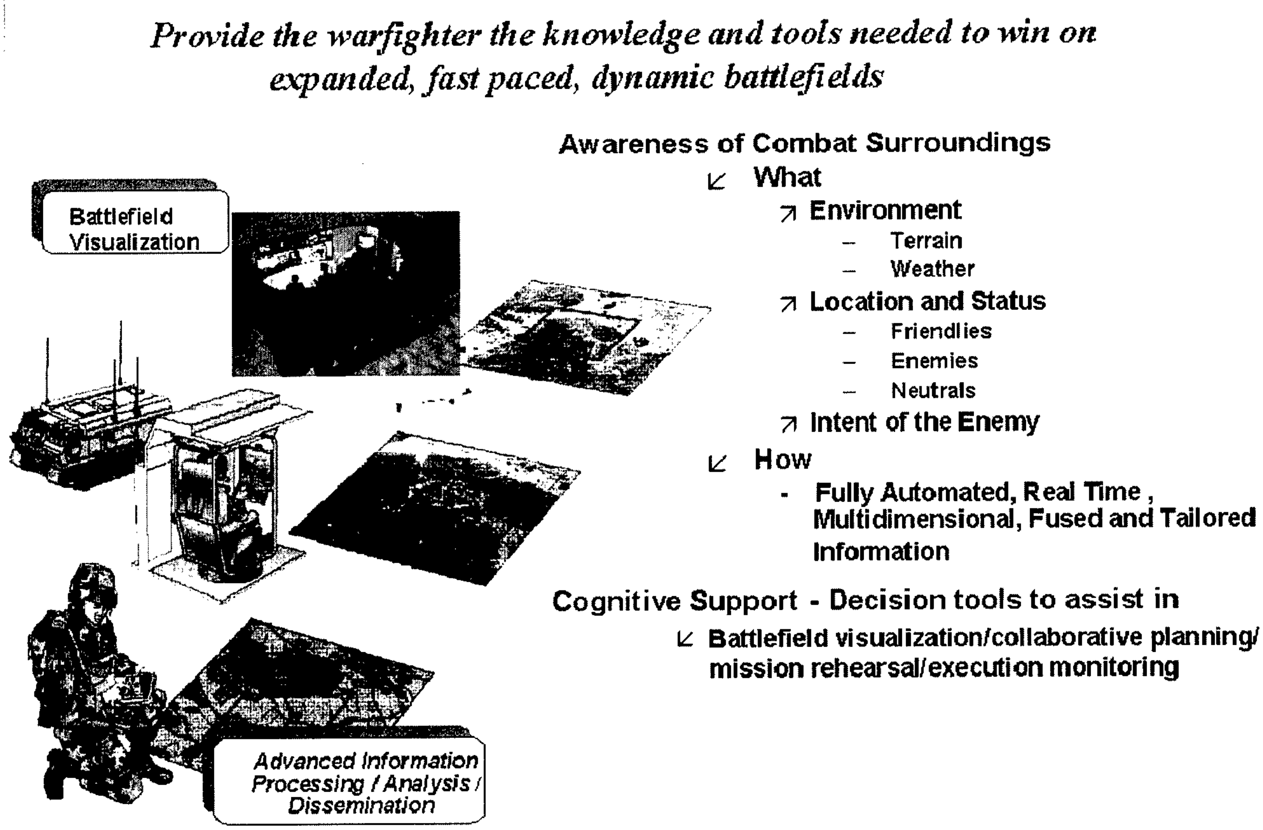


FIGURE III–7. ARMY'S CONCEPT FOR COMMAND AND CONTROL

RAPID TERRAIN VISUALIZATION (RTV) ACTD (1997–01). The goal of this ACTD is to demonstrate capabilities to collect source data and generate high-resolution digital terrain databases quickly to support crisis response and force projection operations within the timelines required by the joint force commander. Since the commander will be capable of integrating terrain databases with current situational data, he can manipulate and display the integrated databases to achieve operational objectives and visualize a desired end state. Source data collection, digital terrain database generation and tailoring, database dissemination, and applications software will be integrated and evaluated. *Supports:* PM–Combat Terrain Information Systems.

BATTLESPACE TACTICAL NAVIGATION (BTN) STO (1999–03). Accurate position/location information is a key component for situational awareness. This program will develop technology and integration concepts to improve the robustness of navigation systems and minimize registration errors between sensors and databases. Under BTN, the Global Positioning System (GPS) signal reception in hostile ECM environments will be enhanced by the deployment of GPS pseudolites and the incorporation of antijam GPS technology. Backup position and navigation capabilities will be provided via the integration of devices suitably scaled to the platform and mission requirements. Sensor and database registration error will be minimized through advanced algorithms. *Supports:* Agile Commander ATD, Land Warrior (LW), PEO–Aviation, FCS.

COLLABORATION TECHNOLOGY FOR THE WARFIGHTER TD (1999–02). This program will demonstrate the ability of the military decisionmaker to operate within the enemy's decision cycle by compressing the observe–orient–decide–act loop. This initiative is unique in that it is a blending of leading-edge commercial-off-the-shelf (COTS) products with research products under development for the future computing environment and tailored to work with emerging battlefield visualization technologies. The technical concept is to push or advance the integration of technologies from basic research conducted in battlefield visualization, input/output modalities, intelligence, low-bandwidth videoteleconference/compression, and writing analysis and icon recognition optical character reader into a collaboration or decisionmaking aid toolset. *Supports:* Agile Commander ATD, FCS.

LOGISTICS COMMAND AND CONTROL (LOG C^2) ATD (1999–03). This ATD will demonstrate automated decision support software tools to enable combat commanders to plan weapon systems crewing and demonstrate enhanced logistics COA analysis capability for reduced planning time and increased number of operational scenarios evaluated. (See Section III–M, "Logistics," for additional information.) *Supports:* Global Combat Support System—Army (GCSS–A), Army Combat Service Support Control System, FCS.

COMMAND AND CONTROL FOR JOINT INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE (C^2JISR) STO (2002–03). This effort, under the Joint Intelligence, Surveillance, and Reconnaissance (JISR) ACTD, will develop a common C^2 and intelligence object-oriented, distributed tactical database for the brigade to improve C^2 battlefield visualization and COA development and analysis. Intelligent agents will provide smart access to and correlation of all battlefield information to enhance situational awareness and reduce information overload of workstation operators. *Supports:* JISR ACTD, Agile Commander ATD, PM–ATCCS, PEO–C^3S, FCS.

E-SUSTAINMENT TD (2004–06). This Wholesale Logistics Management Program (WLMP) will operationally demonstrate the integration of the Army's wholesale and retail logistics systems, initially for the BCT and eventually to a corps-sized task force. E-Sustainment will take the GCSS–A web pilot and enhance it through the infusion of commercial supply chain management software. It will seamlessly integrate with the WLMP Enterprise Resources Plan software modules to automate requirements determination, distribution management, stores management, production scheduling, and facilities planning. *Supports:* PM–GCSS–A, PM–WLMP, FCS.

WARRIOR/PLATFORM COMMAND AND CONTROL TD (FY05–08). This program will develop an demonstrate enhancements of C^2 tools available to the warfighter, emphasizing digital C^2 products and tools that are usable across brigade and below Army platforms, including the dismounted warrior. Candidate products and technologies include low-power electronics architectures, hands-free human–computer interface, knowledge-based situational awareness, distributed collaborative battle planning, mission rehearsal and distance-based training, automated COA deter-

mination, and precision sensor tasking. The program will also develop capabilities for units to conduct instrumented tactical engagement simulations to support spiral development, training, operations rehearsal, and post-operation after action reports. *Supports:* FCS.

AGILE COMMANDER ATD (2000–04). The Agile Commander ATD will demonstrate a dispersed, highly mobile command post that provides the commander with continuous, responsive, proactive, real-time battlespace management information during both stationary and mobile operations. By leveraging DARPA initiatives (Command Post of the Future and Global Mobile (GloMo)) and ARL's work in advanced battlefield planning processing technology, the Agile Commander will provide a scalable and reconfigurable C^4I multifunction operator environment with access to all command post information. This program will integrate the capabilities of the Multifunctional On-the-Move Secure, Adaptive, Integrated Communications (MOSAIC) ATD for mobile demonstration. *Supports:* FCS.

b *Communications*

The success of the FCS is dependent on the ability to provide assured networked communications. The communications grid will be the common, ubiquitous "always on" robust infrastructure and comprises the entry fee for network-centric warfare. The communications grid will provide virtual connectivity between any FCS entities almost instantaneously and on demand via a plug-and-play type of architecture. This architecture will be comprised of individual elements or "cells" that can be added or deleted from the network on an ad hoc basis, much the way the commercial internet is constructed. There are six key technology areas supporting seamless communications: mobile networking, unattended sensor networking, information assurance, antennas, secure personal communications, and reachback. Figure III–8 depicts the Army's networked communications concept to support and enable the battlespace. Specific communications demonstrations and system descriptions follow for each of the six elements.

1) Mobile Networking

Mobile networking provides the connectivity that allows for steady, uninterrupted, wireless on-the-move (OTM) communications in-depth to support OTM operations. Several key communications technology capabilities will be demonstrated via the following Army advanced technology programs.

MULTIFUNCTIONAL ON-THE-MOVE (OTM) SECURE ADAPTIVE INTEGRATED COMMUNICATIONS (MOSAIC) ATD (2000–04). Army transformation to the Objective Force requires mobile forces and command and control capability while on the move. The goal of this program is to provide integrated, self-organized, on-the-move networked communications to support short range (<1 km), medium range (<10 km), and extended-range (>10 km) wireless elements capability. MOSAIC has three major areas of focus: (1) bandwidth management—scaled bandwidth request based on precedence, support of bandwidth reservation, proxies to drive bandwidth-aware applications, and the addressing of IP Quality of service (QoS) over tactical wireless links; (2) adaptive network protocols to support infrastructure mobility—ad hoc network protocols to support self-initializing, self-healing, adaptive, mobile networks while addressing security; and (3) enhanced communications capability through the integration of commercial- and DoD-leveraged technologies—products from internal 6.2 efforts, DARPA products, and commercial products will be leveraged and integrated to demonstrate this mobile capability. Mobile protocols will be integrated into a prototype short-range wireless system followed by integration of mobile protocols into a prototype, medium-range wireless system and an airborne relay. An initial limited field

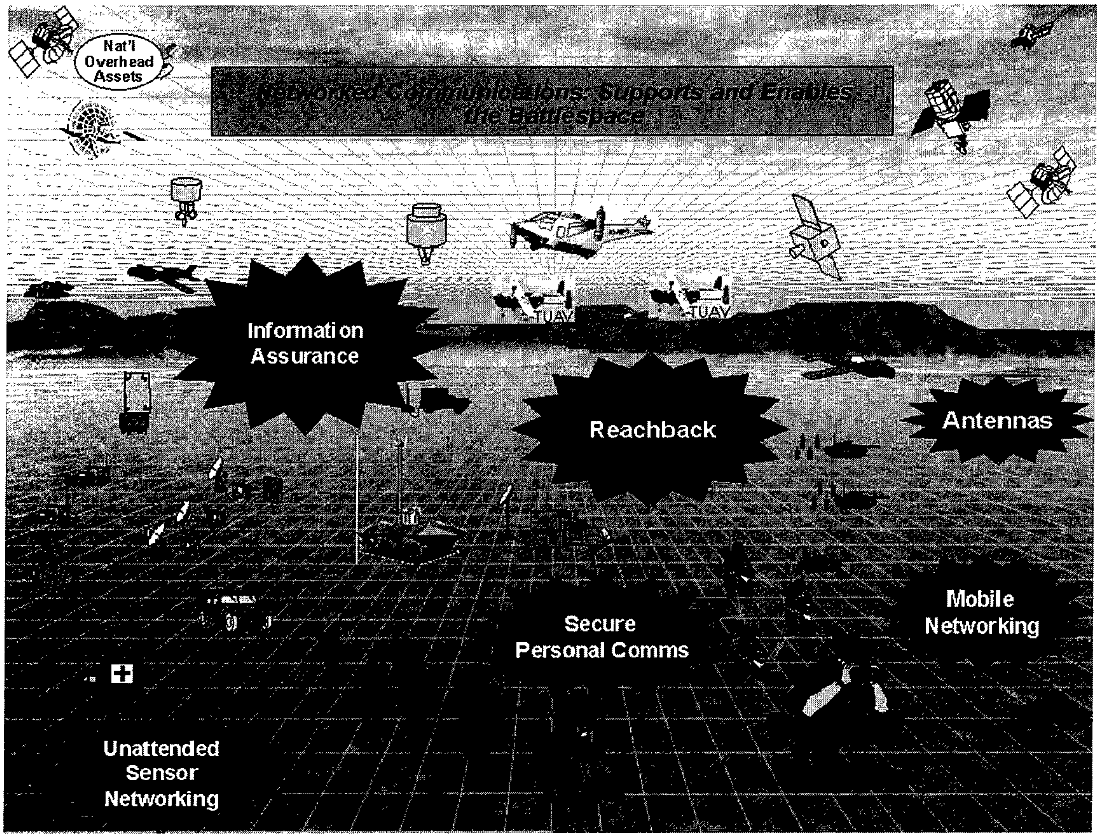


FIGURE III–8. THE CONCEPT FOR NETWORKED DECISIONMAKING

demonstration will be performed, and a laboratory demonstration will be conducted of the integrated protocols, agents, and proxies that provide bandwidth management and support IP QoS and ad hoc networking. All this will culminate in an integrated demonstration with airborne relay, space-based assets, and terrestrial systems. *Supports:* PM–TRCS, PM–WIN–T, PM–MILSATCOM, JTRS, FCS.

ARMY COMMUNICATIONS INTEGRATION AND COSITE MITIGATION (CICM) STO (1997–01). The CICM vision is to enable communication systems integration of the future Joint Tactical Radio System (JTRS) into Army tactical platforms through the application of JTRS ancillary communications products developed under the CICM and Antenna Communications Across the Spectrum (ACAS) STO. The objectives of the CICM program are threefold. First, develop separate VHF and UHF multiplexer prototypes using advanced cosite mitigation technologies to reduce the cosite interference problems that occur when multiple radios are integrated within a mobile communications command post platform. Second, develop wideband power amplifiers that eliminate dissimilar legacy radio amplifiers and their logistics, training and maintenance infrastructures. Lastly (but certainly no less important), develop a JTRS interface for the wideband power amplifiers and multiplexers to facilitate operation with the future JTRS radio. Field tests and the JTRS Integration and Cosite Laboratory will be used to evaluate CICM products using the multiband JTRS OTM antennas developed under the ACAS STO. *Supports:* JTRS; all mobile, multiband communications systems.

NETWORK MANAGEMENT ASSISTANT (E-ASSISTANT) TD (2005–07). The goal of this effort is to provide a network-oriented, automated, self-healing, global network management capability that lever-

ages the commercial base technology and dynamic readdressing and management and that develops algorithms and rule sets to provide solutions optimized for tactical operations. E-Assistant will mature the next generation of tools and algorithms required to provide comprehensive network planning, centralized management, smart allocation of throughput (network telemetry), performance management, global interoperability, spectrum engineering and control, reconfiguration (to include adjustment, corrections, and reallocations), automated monitoring of tactical systems, detailed planning engineering capable of engineering 100 percent of global information systems, and high-level planning based on the operational plan and execution plan. *Supports:* FCS.

ARMY.COM TD (2005–07). This demonstration will focus on providing a seamless, secure, self-organizing, self-healing tactical 3D communications backbone capable of bringing web-like Internet capabilities to the individual soldier on the battlefield, currently available only on commercially wired networks. The objective of this effort is to bring this powerful capability to the wireless environment of lower echelon Army users. The individual soldier will then have a greatly enhanced capacity to perform his mission allowing him to obtain the information he needs, anytime, untethered to a fixed infrastructure. Army.com focuses on providing moderate- to high-bandwidth wireless communications to handheld and vehicle-mounted devices to provide internet and intranet services. Commercially developed digital personal communications system (PCS) services, JTRS, and other emerging communications and internet technologies will be leveraged. Secure and nonsecure networks will be connected to provide a secure environment. This capability will be applicable to both command post and dismounted soldier applications. A significant portion of this program will also focus on networking for unmanned aerial vehicles and SATCOM (i.e., reachback). *Supports:* JTRS, FCS.

2) Unattended Sensor Networking

One of the most critical new areas required for FCS is the need for a robust networking capability for "unattended" sensors. Unattended devices will be internetted to provide access to the information from anywhere in the communications grid, thus allowing for remote control and remote access.

SMART SENSOR COMMUNICATION NETWORKS (SSCN) STO (2001–05). The objective is to develop communications network solutions for forward-deployed, unmanned, clustered entities such as smart munitions, sensors, and robotic systems that will be deployed with the FCS on the digitized battlefield of the future. Sensor technology enables the identification and tracking of enemy movements—critical to survival of a lightweight force. Unfortunately, energy-efficient, networked communications capabilities for miniature microsensors do not exist. The solution will enable adaptive, self-healing, multihop communications networks with optimal routing algorithms that are secure and that simultaneously exchange imagery and data traffic among the clustered entities and rearward to all echelons including all those beyond line of sight. Specific technological challenges include the development and adaptation of network protocols; low-cost and low-power radio technologies; high-efficiency, low-profile antennas; near-Earth propagation effect on antennas; and resolution of security issues associated with linking forward unmanned entities with the (secure) Tactical Internet. *Supports:* Antipersonnel Landmine Alternative, FCS.

3) Information Assurance

Information assurance means that the network can prevent or detect information warfare intrusions into tactical networks (both external and internal) in a timely manner. Information assur-

ance technology is an integral part of the security architecture for FCS. Key Army advanced technology programs in support of information assurance follow.

TACTICAL COMMAND AND CONTROL PROTECT ATD (1998–02). This ATD will develop, integrate, validate, and demonstrate hardware and software that protects the systems and networks of the First Digitized Division and FCS from modern network attacks. A security architecture will be developed and demonstrated to provide advanced network access control, intrusion detection and response, malicious code detection and eradication, and security management within tactical communications networks. The ATD leverages existing attack and protect COTS and DoD protection technologies. Field tests and demonstrations will be conducted for RF and wire-based attacks against threat information systems and against C^2 protect products. *Supports:* Tactical Internet, ABCS, PEO–C^3S, FCS.

TACTICAL INFORMATION ASSURANCE TECHNOLOGY TD (2003–07). The need to provide adequate information protection for the information systems of the FCS and beyond will continue to be a critical necessity that requires further advances in technology and protection tool development. This program will focus on advancing the state of the art in tactical protect tools and security architecture concepts to enhance the security posture of the digitized force. Advanced security tools that are "network aware" will be pursued at all echelons. System vulnerabilities will be examined based on emerging threats and tools focused in those areas. Advanced tools will be pursued in areas of next-generation intrusion detection sensors, trusted operating systems, tactical biometrics, high-speed tactical guards, computer inoculation, and tactical virtual private networks. DARPA, ARL, the Air Force, and NSA efforts in these areas will be leveraged and tailored to tactical needs. Linkages among tools at various echelons will be pursued to provide an information assurance common operational picture for a situational-awareness-type security view. *Supports:* PM–WIN–T, FCS.

4) Antennas

Antennas represent the "spinal cord" of Army tactical communications. Current antenna technologies are incapable of meeting the data transport needs of the Objective Force. Vehicle size, OTM communications needs, and data throughput requirements necessitate development of significant leap-ahead antenna technologies providing small, affordable phased array antennas, conformal antennas for vehicles and dismounted soldiers, and high-gain multiband antennas.

ANTENNAS FOR COMMUNICATIONS ACROSS THE SPECTRUM STO (1997–01). The objective of this demonstration is to develop, leverage, and apply emerging antenna technology to reduce the number of antennas, reduce the visual signature (conformal), reduce the cosite and control problems, and increase efficiencies and radiation patterns in the ranges of 2 MHz to 2 GHz for FCS operations. A second goal is to provide OTM SATCOM antenna capabilities in the X and EHF bands. Eight different technologies will be explored to address different applications (JTRS, air and ground vehicles, SATCOM). Wideband technology (30–450 MHz) will be exploited for JTRS application. For air and ground vehicles, structurally embedded reconfigurable antenna technology and structure-tuned antenna/band-switched techniques (225–450 MHz and 30–88 MHz) will be used. SHF and EHF low-profile, self-steering, OTM antenna technology will be applied to SATCOM applications. The initial thrust will be to address the broadband requirements for JTRS. *Supports:* JTRS, PEO–C^3S, FCS.

ADVANCED ANTENNAS STO (2002–06). The objective is to develop a family of highly efficient, practical, cost-effective antennas and subordinate products covering the 30-MHz to 44-GHz frequency range. These antennas will have higher gain and bandwidth to sustain robust, high-data-rate communications; greater agility for OTM operations; and lower profiles for reduced platform visual signatures. They will also be capable of conformal integration within soldiers' clothing for improved mobility and survivability, and be functional with the JTRS multiband radio. The body-borne and low-profile antennas will avoid more destructive environmental and ballistic impacts, resulting in substantially reduced attrition rates and logistic burdens. *Supports:* JTRS, PEO–C^3S, FCS.

5) Secure Personal Communications

Secure personal communications provide the dismounted warrior with low-power, lightweight communications capability that ensures seamless connectivity with emerging military upper echelon communications systems and other organic tactical sensors. The following represents significant Army personal communications systems and demonstrations.

DISMOUNTED WARRIOR COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, AND INTELLIGENCE (C^4I) TECHNOLOGIES TD (2000–04). Advanced C^4I technologies emerging from this effort will assist in the definition and development of C^4I architectures at echelons battalion and below in support of FCS initiatives. Significant military and commercial investments will be exploited in wireless personal communications, mobile computing, and C^2 applications to ensure power, weight, and cost objectives are met and that C^4I technologies and architectures are optimized for transition through the LW Modernization Strategy and JTRS JPO. This will be accomplished through technical collaboration with DARPA; AMC S&T initiatives identified in the U.S. Army Soldier and Biological Chemical Command Warrior Systems Modernization Strategy; advanced C^4I technologies and architecture designs emerging from the DARPA Small-Unit Operations (SUO) Situation Awareness System, GloMo programs, and commercial developers of consumer electronics and wireless communications products. *Supports:* JTRS, PEO–C^3S, FCS.

UNIVERSAL HANDSET TD (2005–07). The goal of this program is to develop and demonstrate the ability to have multiple personal communications modes (e.g., terrestrial, satellite, peer to peer, local loop) in a single handheld device. This will evolve and mature the work begun under the universal handset Dual-Use S&T program, which is building proof-of-concept prototypes incorporating peer-to-peer waveforms within a cellular PCS handset. Commercial technology will be leveraged to the maximum extent possible. The concept of the universal handset is to incorporate military-unique features using the commercial cellular handset as the basis. The design of a peer-to-peer capability would allow a single handset to be used at all echelons of the battlefield. This would allow dismounted soldiers to be able to communicate within the team as well as having a reachback into the tactical switched network. All of the above modes would be secured using the CONDOR program as the cornerstone of security. This program is critical, as these developments are not ongoing commercially. *Supports:* Light Forces, FCS.

6) Reachback

One of the key elements to attain the goals of deploying a brigade-size fighting force within 96 hours and a division in 120 hours will be taking only those forces that directly engage an adversary while, to the maximum extent possible, leaving behind support and staff elements at intermediate staging bases or in a sanctuary. A strong reachback communications capability is critical for attaining this goal. Objective Force command elements will no longer be tied to large easy-to-

hit tent and antenna farms but rather will be located in highly mobile C^2 vehicles, communicating while on the move via satellite or autonomous air vehicle. This will enable the commander to minimize the numbers of staff, intelligence and logistics personnel while still using their outputs via long-range communications assets. To achieve these goals, several key technologies will be developed to communicate with overhead assets while OTM and increase communications throughput.

ON-THE-MOVE TACTICAL SATELLITE COMMUNICATIONS (SATCOM) TECHNOLOGY STO (2000–04). The goal is to develop an OTM SATCOM ground terminal capability that can quickly recover from signal blockages due to manmade objects, terrain or foliage, weather, and other atmospheric effects. These terminals will be used in conjunction with emerging wideband commercial low-Earth-orbit (Teledesic, Sky Bridge, etc.), medium-Earth-orbit, and military geosynchronous-Earth-orbit SATCOM and protected (advanced EHF) narrowband SATCOM. *Supports:* PM–MILSATCOM, FCS.

NEXT-GENERATION SATELLITE COMMUNICATIONS TD (2005–07). The objective is to develop a universal, modular, adaptive SATCOM terminal (UMAST) to support the evolving 3D military global information infrastructure (GII). These terminals will be smaller, lighter, and cheaper than current terminals. They will be easily deployable for both ground and airborne operations and will operate while OTM. They will interface seamlessly with the terrestrial wired and wireless communication systems to integrate wide and local area battlefield networks into an intranet providing the warfighter with range-independent, secure, global connectivity. *Supports:* GII, FCS.

3 Roadmap

Figure III–9 presents the roadmap for Army C^4 modernization. It reflects the advanced technology (6.3) science and technology demonstrations being developed in support of battlefield digitization and FCS. Army laboratories and research centers are working cooperatively with industry and academia to ensure a strong U.S. defensive posture and to protect the soldier—our greatest asset.

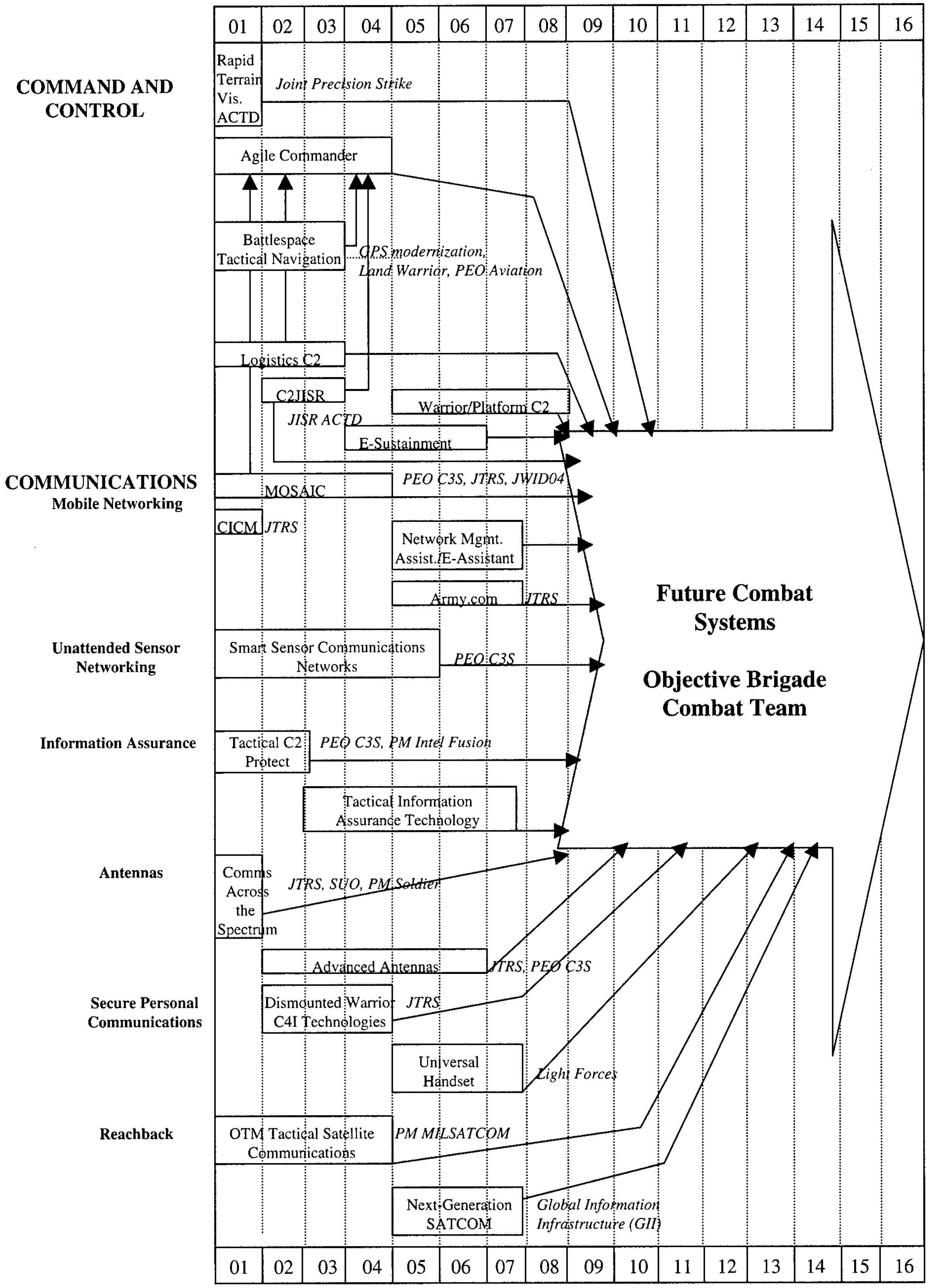


FIGURE III–9. ROADMAP—COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS

E INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE AND ELECTRONIC WARFARE

Army intelligence modernization and the resulting intelligence, surveillance, reconnaissance, and electronic warfare (ISR & EW) capabilities in support of the Objective Force enable the U.S. Army to gain information dominance. Information dominance is key to achieving the enhanced operational concepts outlined in the Army's Vision. Achieving information dominance requires building up and protecting friendly information capabilities, exploiting enemy information systems, and degrading enemy information capabilities. To employ these capabilities, future commanders must:

- Conduct multidimensional and simultaneous operations.
- "See" their battlespace in depth, often in real time.
- Share an accurate, common picture of the joint battlespace, horizontally and vertically.
- Precisely locate, identify, track, and attack high-payoff targets with lethal and nonlethal means, and conduct battle damage assessments (BDAs).
- Protect their forces throughout the operation.
- Operate with combined, joint, and multinational forces and with governmental and nongovernmental organizations.
- Track friendly forces.

To that end, the focus of tactical ISR (TISR) is on the "sensor grid" (Figure III–10). This software-driven, web-based sensor grid design offers a flexible user-friendly environment that allows broad access with minimal training. The goal is a "seamless system-of-systems."

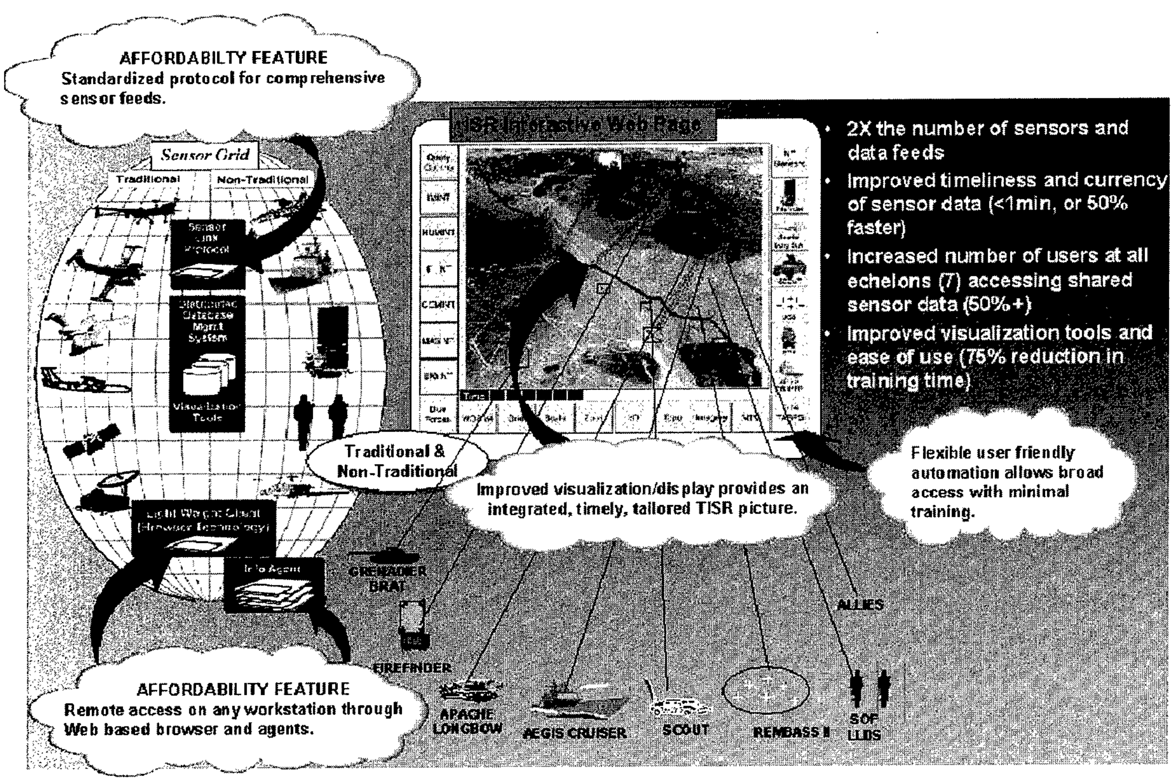


FIGURE III–10. ISR FOCUS ON THE SENSOR GRID

1 Modernization Strategy

The long-term goal of Army ISR & EW modernization is to evolve an integrated battlespace information system that provides for the information collection, integration, analysis, presentation, and denial functions required for the 21st century to meet the intelligence and electronic attack requirements of the warfighter. The strategy is to develop an open systems architecture to allow for continuous modernization of the ISR & EW mission area and to provide multimission systems on common carriers for a tailorable, scalable, and complementary mix of airborne and ground-based sensors, processors, and jammers.

The Army's Intel XXI concept supports Force XXI and the Army's Vision. It is based on the requirement to provide intelligence support to warfighters and joint and ground component commanders across the continuum of the 21st century military operations. The emphasis is on intelligence to support our force projection Army in the information age. Intel XXI's primary objectives are to provide to the commander a virtual, near-real-time continuous picture of the battlespace, intelligence support for force protection, targeting, and BDA. These objectives drive requirements for sensors, processors, and communications capabilities.

Table III–5 summarizes Army ISR & EW advanced technology programs depicted on the ISR & EW roadmap (Figure III–11). Systems and system upgrades are the first step in fulfilling the ISR & EW strategy. These will evolve from current systems through the use of product improvement programs and preplanned product improvements (P^3Is). TDs and ATDs will be utilized to facilitate the transition of technology through block improvements to new or existing systems. The challenge is to field a family of ISR & EW systems that use a common module open architecture, thus improving flexibility, reducing the logistics burden, and minimizing development costs.

TABLE III–5. ISR & EW DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Information Collection—Ground-Based Systems Multifunction Staring Sensor Suite **Information Collection—Airborne Collection Systems** Multimission/Common Modular Unmanned Aerial Vehicle Sensors Integrated Situation Awareness & Targeting **Denial Systems** Tactical Command & Control Protect	**Information Collection—Ground-Based Systems** Warfighter Electronic Collection & Mapping (STO) Multimission Radar (STO) **Information Collection—Airborne Collection Systems** Common Air/Ground Electronic Combat Suite Small-Unit Unmanned Aerial Vehicle Synthetic Aperture Radar Multimode, Multiband Unmanned Aerial Vehicle Synthetic Aperture Radar, Moving Target Indicator, and Foliage Penetration Radar	**Intelligence Processing & Fusion** Owning the Weather **Denial Systems** Network Emitter Targeting & Attack Integrated Countermeasures (STO) Objective Force Targeting & Information Warfare Objective Force Protection Counter Intelligence, Surveillance, & Reconnaissance
Advanced Concept Technology Demonstration		
Intelligence Processing & Fusion Joint Intelligence Surveillance, & Reconnaissance		

System/System Upgrade/Advanced Concept	
System Prophet (Ground) **System Upgrade** All-Source Analysis System Upgrades Integrated Meteorological System Suite of Integrated Infrared Countermeasures (ALQ–212) Suite of Integrated Radio Frequency Countermeasures (ALQ–211) Laser Warning Receiver (VVR–1)	Shortstop Electronic Protection System Meteorological Measuring Set Army Tactical Internet **Advanced Concept** Distributed Intelligence & Electronic Warfare Fusion Profiler Integrated Command, Control, Communications, Intelligence, and Electronic Warfare System of Systems Future Combat Systems

2 System Demonstrations

The ISR & EW technology subareas are Ground-Based Collection Systems, Airborne Collection Systems, Intelligence Processing and Fusion, and Denial Systems.

a *Information Collection—Ground-Based Collection Systems*

Ground-based collectors for ISR & EW ground-based collection systems are targeted against multiple echelons. They embody modular, scalable, multisensor capabilities that combine electronic intelligence (ELINT), communications intelligence (COMINT), and electronic attack.

WARFIGHTER ELECTRONIC COLLECTION AND MAPPING (STO) (1999–03). This program will develop and demonstrate a capability for automated electronic collection and mapping of the battlefield by providing a real-time RF collection and corresponding warning capability at the squad/small-unit level depicting enemy and friendly locations, enemy intent, language understanding, and operational forces composition of the near battle. As part of the program, a digital reconfigurable receiver will be demonstrated. It will intercept very wideband signals in a single-channel mode and resolve narrowband signals spatially in a multichannel mode. *Supports:* Prophet, Multi-Intelligence Reporting and Sensor System.

MULTIMISSION RADAR (MMR) STO (2002–06). MMR will develop an HMMWV/FCS-configured sensor for reconnaissance, surveillance, target acquisition, situational awareness, and alerting and cueing. MMR will enable the Army to rapidly deploy a single sensor that will perform multiple missions (e.g., counterfire target acquisition, air defense) while also simultaneously providing data to intelligence, maneuver, air traffic control, etc. Small and light enough for insertion via single CH–47 or C–130 sortie, yet with long-range target acquisition capabilities, MMR will support the Objective Force as well as light and heavy forces. MMR will support digitization of the battlefield and provide single-sensor situational awareness in situations where multiple sensors cannot be readily or expediently deployed. In theaters where MMR is the only sensor available, logistics support to the theater will be significantly reduced. *Supports:* FCS, PEO–IEW&S.

MULTIFUNCTION STARING SENSOR SUITE (MFS^3) ATD (1998–01). This ATD will demonstrate a modular, reconfigurable MFS^3 that integrates multiple advanced sensor components, including a staring IR imager, a multifunction laser, and acoustic arrays. The MFS^3 will provide scout/cavalry vehicles and amphibious assault vehicles with a compact, affordable sensor suite for long-range noncooperative target identification, mortar and sniper fire location, and air defense against low-signature targets. The IR imaging system will be configured to accommodate either visible-to-mid IR or far IR focal plane arrays. As single focal planes capable of operating across the full optical spectrum mature, these may be inserted into the assembly. The staring IR sensor will operate at high field rates to allow sniper and mortar detection, in addition to the conventional target acquisition functions. Integration of a multifunction, multiwavelength laser system will incorporate ranging, range mapping, target profiling, and laser designation to support target location, target cueing, aided target identification, and target designation. The acoustic array will provide target cueing and location and will assist in automated targeting functions. *Supports:* FCS, Marine Corps Advanced Amphibious Assault Vehicle.

b *Information Collection—Airborne Collection Systems*

Airborne information collection is comprised of manned and unmanned platforms. The manned aircraft will undergo P^3Is that will add required capabilities on an incremental basis.

MULTIMISSION/COMMON MODULAR UNMANNED AERIAL VEHICLE SENSORS ATD (1997–01). This ATD will provide a low-cost, lightweight, EO/IR integrated moving target indicator (MTI) radar/synthetic aperture radar (SAR) payload for integration on future tactical unmanned aerial vehicles (UAVs). The radar payload will build on successes in the current low-cost radar development program and will likely utilize a monolithic microwave integrated circuit (MMIC). The forward-looking infrared radar will take advantage of high-quantum efficiency, 3.5-μm staring arrays. These sensor payloads will provide enhanced reconnaissance, surveillance, BDA, and targeting for non-line-of-sight weapons. *Supports:* Tactical UAV Intel Package, Prophet.

INTEGRATED SITUATION AWARENESS AND TARGETING ATD (1999–02). The purpose of this ATD is to demonstrate an integrated multispectral suite of warning sensors that will provide Army aviation and ground vehicles with full-dimensional protection and precision targeting, and assist with combat identification and real-time, bidirectional datalinks to other aircraft, ground vehicles, and fusion centers. (See Section III–C, "Aviation," for more detailed information.)

COMMON AIR/GROUND ELECTRONIC COMBAT SUITE (CAGES) TD (2004–08). This project will demonstrate an integrated modular multispectral RF, IR, and laser electronic combat suite for air and ground vehicles that provides multifunctional roles of precision targeting, situational awareness, real-time bidirectional C^3I feeds, and countermeasures against future multirole air and ground attack weapons with multispectral, RF, IR, UV, and EO sensors. Both conventional and low-observable platforms will be addressed through low-cross-section sensors and specially tailored countermeasures to deceive and reduce detection by remote sensors. *Supports:* P^3I to ALQ–211, ALQ–212, and VVR–1; Integrated C^3IEW System-of-Systems.

ADVANCED ELECTRONIC WARFARE SENSORS TD (1999–03). This project will develop horizontal technology integration-capable, low-cost, uncooled, two-color IR missile warning sensors for ground vehicle protection horizontally integrated to the Advanced Threat IR Countermeasures ALQ–212. The missile warning sensors will provide precision angle of arrival of missile launch at the maximum weapon launch range and cue countermeasures.

SMALL-UNIT UNMANNED AERIAL VEHICLE (UAV) SYNTHETIC APERTURE RADAR (SAR) TD (2007–10). This program is intended to increase the capability provided by today's existing UAV SAR technology. UAVs extend target acquisition for dismounted forces and improve sensor-to-shooter linkages. Advanced sensors for UAVs will increase information and intelligence to commanders, providing a meaningful picture of the dynamic battlefield. *Supports:* Integrated C^3IEW System-of-Systems.

MULTIMODE, MULTIBAND UNMANNED AERIAL VEHICLE (UAV) SYNTHETIC APERTURE RADAR (SAR), MOVING TARGET INDICATOR (MTI), AND FOLIAGE PENETRATION (FOPEN) RADAR TD (2011–16). This program will develop a small, lightweight, low-power, multimode radar with SAR, MTI, and FOPEN capabilities. It will have coherent change detection and interferometric capability to provide very high imaging to include ground texture to see tracks and mines. The FOPEN capability will provide the ability to selectively image inside buildings to find combat vehicles hidden in buildings and under trees. *Supports:* FCS block upgrades.

c *Intelligence Processing and Fusion*

The objective of intelligence fusion and processing modernization is the development and fielding of common hardware and software for intelligence analysis centers. The goal is to shorten

timelines for supplying intelligence to the commander and to provide real-time target information to weapon systems.

JOINT INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE (JISR) ACTD (1999–05). The objective of JISR is to provide new capabilities for the brigade commander in the form of distributed, nonlinear battlefield operations and an independent mode of brigade intelligence operations. The brigade commander will be able to access intelligence data in real time from a combination of national and tactical assets. The integration of bottom-up and top-down data into a true common snapshot of the battlefield will enable the commander to "see" an extended battlespace and make effective command decisions in a timely manner. The principal technical objective is to develop a set of tools and a prototype collection management for C^2 and operational tasking of TISR sensors and platforms. The end product will permit commanders to visualize the unfolding of ISR operations with respect to high-priority target identification, location, and tracking. *Supports:* ASAS, Prophet.

OWNING THE WEATHER TD (1996–03). This program consists of three interrelated TDs that will transition directly from 6.2 into the integrated meteorological system (IMETS), the field artillery's meteorological measuring set (MMS), the advanced concept profiler, Army Battle Command System (ABCS), battlefield automated systems (BASs), and the M&S community. Target area meteorology will upgrade IMETS and MMS with a battlespace forecasting capability and add computer-assisted artillery meteorology software to the MMS and future profiler for improved accuracy of indirect fire and precision strike. The profiler will replace balloon-borne measuring systems and hydrogen generators on the battlefield. The automated decision aid will enable commanders to apply this improved knowledge of battlefield weather to compare weather-based advantages and disadvantages of friendly and threat systems using automated decision aid client applications on ABCS BASs served by the IMETS through a distributed computing environment. *Supports:* IMETS, MMS, Profiler, ABCS, Distributed Interactive Simulation.

d *Denial Systems*

Denial systems are categorized as jamming, deception, and self-protection systems. The objective of these systems is to deny the enemy vital information and to deceive and disrupt his command and control area surveillance and air defense weapon systems

TACTICAL COMMAND AND CONTROL PROTECT ATD (1998–02). The attack portion of this ATD will demonstrate the ability to launch effective attacks against integrated battlefield area communications systems (threat information systems). The demonstration will use C^2 attack capabilities against Tactical Internet information systems and components. The demonstration will provide the ability to control an adversary's use of information, information-based processes, and information systems selectively through the application of offensive capabilities that deny, disrupt, or degrade operations or capabilities. (Refer to Section III–D, "Command, Control, Communications, and Computers," for information on the protect portion of this ATD.) *Supports:* ICM, Tactical Intelligence C^2 Components and Networks.

NETWORK EMITTER TARGETING AND ATTACK TD (2004–07). The objective of this project is to demonstrate a detection, targeting, and attack capability against forward and local area networked and netted tactical communications and radar sensors. Frequency coverage will be expanded to cover additional voice and data communications and radar bands with the addition of active deception and jamming modes. This effort will reduce the weight and logistics burden by providing a multifunctional electronic support and attack capability using the same radios used for

unit communication. Emitters detected and attacked will be automatically reported to sites such as the common ground station and All-Source Analysis System (ASAS) databases and emitter mapping. Upgrades to future digital and interim radios will be developed and demonstrated for wideband collection and attack functions using new software algorithms and limited lightweight applique devices. *Supports:* Integrated System-of-Systems, FCS.

INTEGRATED COUNTERMEASURES (ICM) STO (1999–04). The goal is to demonstrate an integrated multi-spectral RF and IR countermeasures capability that will provide Army aviation and ground combat vehicles with full-spectrum protection to counter integrated air defense, antitank guided missiles, top attack, and area surveillance systems. (See Section III–C, "Aviation," for more detailed information.) *Supports:* PM–ASE P^3I to ALQ–211 and ALG–212, CAGES, FCS.

OBJECTIVE FORCE TARGETING AND INFORMATION WARFARE (OFTIW) TD (2008–16). This program will develop and demonstrate common modules for air and ground EW systems that provide the ability to detect, locate, classify, deceive, and jam enemy next-generation tactical communications. Enemy tactical communications will be using a mixture of present and next-generation military tactical radios as well as adaptations of commercial systems that use new modulations, frequencies, power management, and spread-spectrum techniques. This program will demonstrate the ability to counter the future threat with a 50 percent hardware and weight reduction plus a 400 percent increase in system availability to reduce logistics support while still providing full mission performance. *Supports:* FCS block upgrades.

OBJECTIVE FORCE PROTECTION (OFP) TD (2008–16). The goal is to develop and demonstrate common modules for aircraft, ground vehicles, high-value ground systems, and the individual soldier that will provide electronic protection against the full spectrum of guided and homing threat weapon systems. This program will develop multifunctional RF, IR, and EO electronic warfare sensors and active full-spectrum emitters to detect and cue deception and countermeasures and to provide combat identification. Highly integrated sensors and countermeasures will be needed to detect and counter the next generation of surface-to-air missiles, antitank missiles, top-attack munitions, and battlefield surveillance radars that use multiple integrated and netted sensors to defeat the FCS. *Supports:* FCS upgrades.

COUNTERINTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE (ISR) TD (2004–07). Currently the Army has no integrated capability at the operation and tactical level to stealthily access, collect, process, exploit, and nonlethality counter, in real time, adversary ISR. This project seeks to produce capabilities to conduct stealthy offensive intelligence operations and information warfare against modern RF-based C^2 information systems and their connected, computer-based, internet protocol networks at division and below. Cost and vulnerability of forward-deployed, special-purpose threat battlefield communication systems are surmountable barriers to solving this problem as are the insufficient numbers of counter-ISR systems and cyber warriors at echelons of division and below. *Supports:* Integrated C^3IEW Systems-of-Systems, FCS.

3 Roadmap

Figure III–11 presents the roadmap for Army ISR & EW modernization.

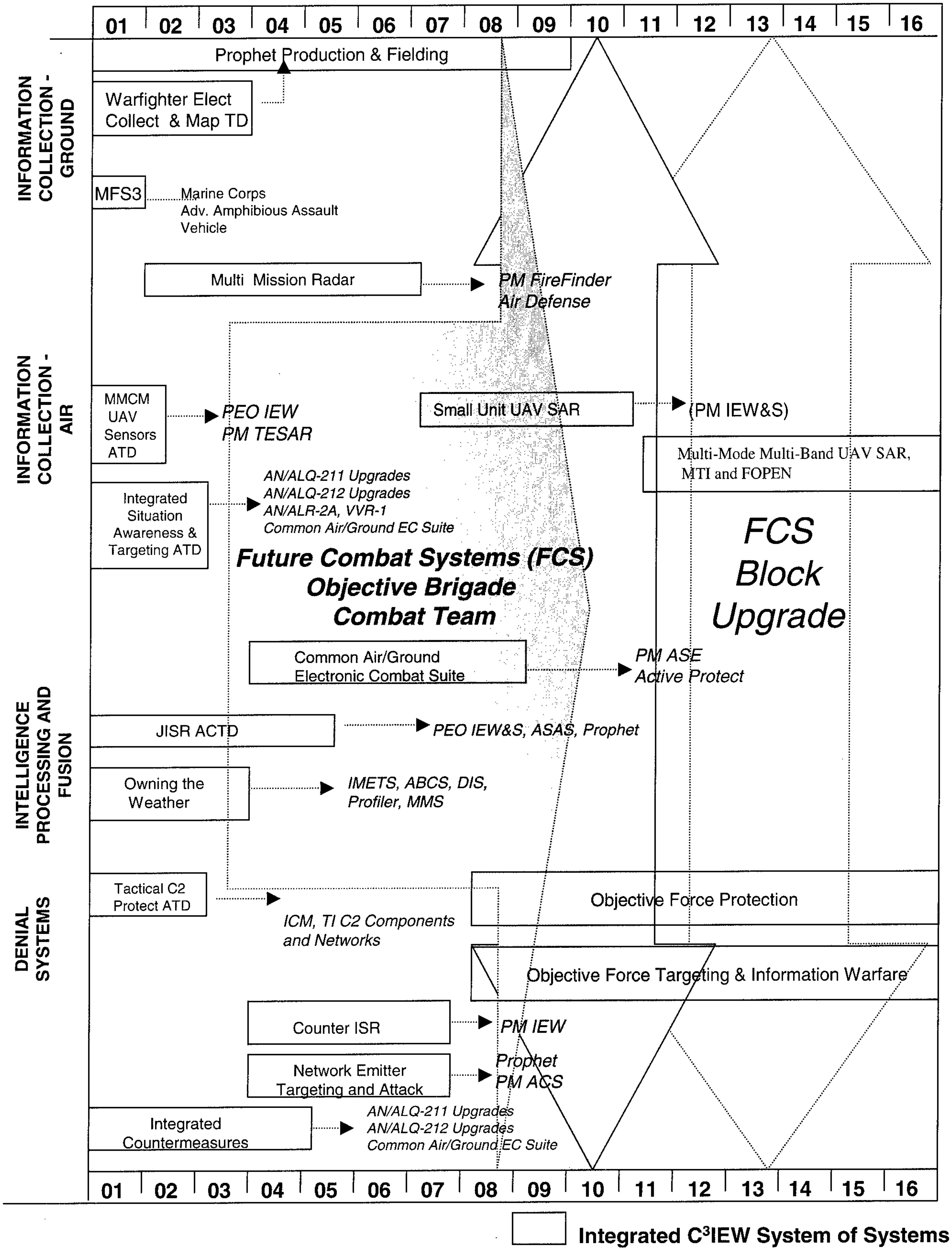


FIGURE III–11. ROADMAP—INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE AND ELECTRONIC WARFARE

F GROUND COMBAT AND TACTICAL SYSTEMS

Today's Army needs to rapidly deploy forces for worldwide contingency missions. Current ground combat systems have decisive overmatch, but take too long to deploy, have a large logistics tail, and are not well suited to operational environments with limited infrastructure. Current combat vehicles rely on traditional logistics support for construction and communications.

The Objective Force will be deployed in less time, with less transport, and with reduced logistics, but will maintain or exceed the lethality and survivability of the Legacy Force. Innovative designs using a system-of-systems approach, robotics, smart weapons, and survivability advances can lead to a fully air-deployable armored assault force.

Ground combat systems require targeting, location, and acquisition systems capable of rapid detection, recognition, identification, handoff, or engagement of both ground and aerial targets beyond the threat detection range. Systems must perform effectively day or night in adverse weather, in cluttered background environments, and in the presence of countermeasures that include jamming and the use of low-observable and active defense systems.

The Army focuses on ground combat and tactical system technologies that give soldiers the capabilities needed to dominate the battle and win the information war. The technologies address Future Combat Systems and Objective Force capabilities. This technology area also supports advanced concepts and system upgrades for the fundamental Army and Marine Corps land combat functions: shoot, move, communicate, survive, and sustain.

1 Modernization Strategy

Dominant maneuver is one of the Army's modernization objectives. The mounted forces section, "Combat Maneuver," in the *Army Modernization Plan* supports this objective by assessing the strengths and weaknesses of mounted forces. This section also outlines a modernization program to correct deficiencies and exploit strengths. It calls for the following major improvements to continue the Army's modernization program: increase target acquisition, digitize the battlefield, increase lethality, increase survivability, and improve force structure. The following integrated concept teams (ICTs) have been formed to ensure that the goals for the modernization strategy are met:

- *Suite of Survivability Enhancements System (SSES) ICT.* The SSES ICT will coordinate the development of a suite of survivability enhancements for ground combat vehicles. This technology will protect the mounted force from known enemy threats.
- *Force XXI Battle Command Brigade and Below (FBCB^2) ICT.* The FBCB^2 ICT will conduct a concept review of C^2 functions and define required operational capabilities for combined arms command and control at brigade and below.
- *Future Tactical Truck Systems ICT.* The ICT will develop requirements and provide concept designs and analysis for the acquisition of future tactical vehicles to support the FCS and Medium Brigade.

Table III–6 summarizes demonstrations and technologies applicable to the Ground Combat and Tactical Systems area.

TABLE III–6. GROUND COMBAT AND TACTICAL SYSTEMS DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
System Integration Future Scout & Cavalry System **Vehicle Electronics** Crew Integration & Automation Testbed Multifunction Staring Sensor Suite **Robotic Vehicles** Robotic Follower	**System Integration** Future Combat Systems (STO) **Integrated Survivability** Full-Spectrum Active Protection (STO) Signature Management for Future Combat Systems (STO) Integrated Countermeasures (STO) Survivability Technology Integration Program (STO)	**Mobility** Ground Propulsion & Mobility (STO) Combat Hybrid Power Systems (STO) Wheeled Vehicle Mobility **Robotic Vehicles** Demonstration III Experimental Unmanned Vehicle Intelligent Mobility Second-Generation Robotics
System/System Upgrade/Advanced Concept		
System Upgrade M1A2 Abrams SEP M2A3 Bradley Interim Armored Vehicle	**Advanced Concept** Future Combat Systems Future Tactical Truck Systems	

2 System Demonstrations

The Ground Combat and Tactical Systems technology subareas are Systems Integration, Integrated Survivability, Mobility, Vehicle Electronics, and Robotic Vehicles (Figure III–12).

a *Systems Integration*

System integration demonstrates the operational potential, technical feasibility, and maturity of advanced combat vehicle technologies through TDs and ATDs. The objectives of system integration are to demonstrate innovative concepts and combat vehicle configurations, technologies, and integration techniques. Achieving these objectives will lead to hardware technology demonstrations, computer simulations, and full-scale demonstrations that accomplish a rapid and

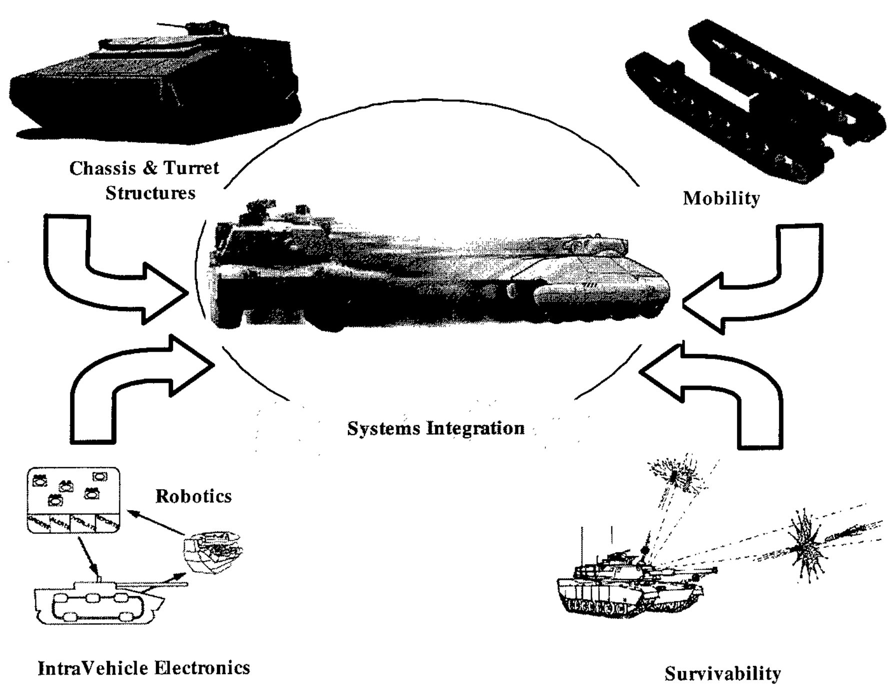


FIGURE III–12. ADVANCED GROUND VEHICLE TECHNOLOGIES FOR THE MOUNTED FORCE

seamless transition of advanced technologies to system applications. All demonstrations include user and developer teaming in field or laboratory environments.

FUTURE SCOUT AND CAVALRY SYSTEM (FSCS) ATD (1998–02). The FSCS ATD will demonstrate the feasibility and operational potential of an advanced lightweight vehicle chassis integrating scout-specific and advanced vehicle technologies developed in other technology-based programs. The effort will be fabricated and tested in virtual and real environments to evaluate and validate sensors and situational awareness capabilities and to develop scout tactics. The FSCS ATD will develop and demonstrate mobility components such as electric drive, semiactive and fully active suspension, and band track. Other specific technologies that may be integrated into the scout platform include advanced sensors, advanced lightweight structural materials and armors, advanced crew stations, advanced C^2, medium-caliber weapons, and advanced survivability systems. This effort will validate the inherent signature reduction of advanced mobility technologies. The ATD is a technology carrier for possible upgrades to the Interim Armored Vehicle and advanced capability for FCS.

FUTURE COMBAT SYSTEMS (FCS) STO (2000–05). This effort is a collaborative program between DARPA and the Army to evaluate and demonstrate network-centric concepts for a multimission combat system that will be overwhelmingly lethal, strategically deployable, self-sustaining, and highly survivable in combat through the use of integrated C^2 capabilities with unsurpassed situational understanding for all levels of commanders. The goal of the FCS program is to strike an optimum balance between critical performance factors, including ground platform strategic, operational, and tactical mobility, and lethality, survivability, and sustainability. This program will (1) define and validate FCS design and operational concepts using modeling and simulation and surrogate exercises; (2) fabricate and test an FCS Demonstrator with its desired functionalities (direct fire, indirect fire, air defense, nonlethal, reconnaissance, C^2 on-the-move ability to transport troops) suitable for system development and demonstration (SDD) and production; and (3) develop selected enabling technologies for use in the Demonstrator. This program will provide the materiel and operational answers necessary to enable flexible, effective, and efficient multimission forces capable of timely worldwide projection of overwhelming military power. *Transitions to:* SDD in FY06.

b *Integrated Survivability*

Detection avoidance, hit avoidance, and kill avoidance technologies will be developed and integrated to enhance overall vehicle survivability.

FULL-SPECTRUM ACTIVE PROTECTION (FSAP) STO (2000–05). The objective is to deliver an FSAP system design that can be integrated on a ground combat vehicle. The system will provide hemispherical protection for ground combat vehicles against large-caliber threats, focusing on gun-tube-launched kinetic-energy (KE) and high-explosive antitank (HEAT) rounds. FSAP technology will be matured to enter SDD in FY06. The goal is to develop a single universal countermeasure for protection against smart top-attack, hit-to-kill antitank guided missiles (ATGMs) and especially tube-launched KE and HEAT threats. The FSAP approach will be balanced on consonance with advanced armor technology, including development of armor systems, and will consolidate active protection TDs. *Supports:* FCS, Abrams, Bradley, M113, Crusader.

SIGNATURE MANAGEMENT FOR FUTURE COMBAT SYSTEMS STO (2001-05). Signature management currently lacks adequate virtual modeling tools and hardware evaluation technologies to meet FCS requirements. This effort will improve existing modeling tools, characterize advanced hardware,

and provide inputs for FCS concept development. Technologies and hardware approaches from TARDEC, ARL, and contractors will be evaluated to validate performance and improve virtual modeling techniques. Field testing will be used to quantify the performance, burdens, and user acceptance of specific technologies. Virtual model improvements and technical results will transition to the FCS to support FCS concept development and milestone decisions. A requirements analysis for FCS will be completed by FY01. Material and system-level tests will be conducted in FY02 to improve model inputs. Virtual prototypes, computer-aided virtual environment (CAVE) analysis by the Mounted Maneuver Battle Laboratory, and hardware test results in FY03 will support the technology readiness decisions. Additional hardware testing and CAVE evaluation in FY04 will validate FCS modeling results and analysis inputs. The final system evaluations and test validation in FY05 will support the FCS SDD transition. The currently achievable technology base hardware capability is a 50 percent signature reduction at a technology readiness level (TRL) of 4. For transition into FCS SDD by FY05, this effort will demonstrate a 70 percent signature reduction at a TRL of 6. Signature treatment weight and cost will also be reduced 40 percent by FY05.

INTEGRATED COUNTERMEASURES (ICM) STO (1999–04). This program will develop and demonstrate leap-ahead integrated RF, EO, and IR countermeasure upgrades for the AN/ALQ–211 and –212 systems to protect both conventional and reduced signature aircraft with horizontal technology integration to ground vehicles and soldier survivability. Application of selected modules to ground vehicles will provide protection against command-guided ATGMs, fire-and-forget imaging ATGMs, top-attack munitions, and fuzed artillery projectiles for dismounted soldiers. (See Section III–C, "Aviation," for more detailed information.)

SURVIVABILITY TECHNOLOGY INTEGRATION PROGRAM STO (1997–02). This program integrates and demonstrates advanced survivability technologies for protection of ground combat vehicles against multiple threats. Survivability technologies that are integrated and demonstrated include Active Protection System (APS), advanced armors, and electronic sensors and countermeasures. Active protection efforts focus on demonstrating the necessary threat sensors, software algorithms, and hard kill countermeasures needed for an APS. APS will initially be effective against chemical-energy munitions (e.g., shaped-charge warheads) and top-attack munitions, with an ultimate goal of FSAP demonstrating an effective countermeasure against KE (i.e., long rod) by leveraging the FSAP STO. Defeat of KE threats by an APS poses an especially difficult challenge due to the velocity, small cross section, and robustness of long-rod penetrators. Electronic sensors and countermeasures will also be demonstrated against the class of threat for which "soft kill" is more effective. Armor will be tested against small- and medium-KE threats as well as the residual debris from APS-engaged threats. APS and ECM are viewed as having tremendous potential for providing enhanced protection of all combat vehicles and is an especially attractive solution for lightweight vehicle platform classes.

c *Mobility*

Future systems need to be more mobile, agile, and efficient than today's systems. Technology investments in this area seek to improve power generation storage and conditioning for advanced electrical applications. Advancements are needed in both track and wheeled suspension systems. Track systems must assist in weapon stabilization while weighing less than today's suspensions to improve fuel efficiency. Wheeled systems must have greater performance in soft soil, where tracks tend to have a mobility advantage. Tires must have increased resistant to damage. Electric drives will help reduce weight and size of the propulsion system. Advanced fuels

and lubricants will reduce fuel consumption by reducing frictional losses and withstanding higher operating temperatures. Improvements in power management are needed to handle multiple electrical systems with minimal increase in size of the electrical power. Meeting these goals will result in smaller, faster, and more powerful, agile, and frugal systems of the future.

GROUND PROPULSION AND MOBILITY STO (1997–01). Ground vehicle mobility advances for the 2001 combat vehicle fleet will be achieved through smaller and lighter systems with improved weapon stabilization, improved ride and agility, and reduced acoustic and IR signatures. These advantages will be the result of development of several advanced component systems such as band track, semiactive suspension with an active track tensioner, and electric drives. Band track will be developed for vehicles as heavy as 30 tons, providing weight savings and quiet operation. Semiactive suspension will be developed incorporating a track tensioning system that will provide improved fuel economy and better track retention. Electric drive development will center on incorporating running gear technology such as motors and generators that are being developed through cooperative efforts by government agencies (Army, DARPA, DOE, Marine Corps) and industry. By 2001, operational effectiveness of semiactive suspension and band track technologies applicable to the tracked and wheeled fleet will be demonstrated.

COMBAT HYBRID POWER SYSTEMS (CHPS) STO (2000–04). This effort will demonstrate, in both a system integration laboratory (SIL) and a virtual prototype, the feasibility and operational potential of a hybrid electric vehicle power architecture for future military vehicles. A successful demonstration of this architecture would provide the capability to support multiple electric applications (weapons, advanced survivability systems, and improved mobility systems) within the confines of a ground vehicle. This technology may also eliminate the need for dedicated electric generators. Improved mobility means increased cross-country speeds, better acceleration, and improved vehicle fuel economy. Hybrid electric technologies are being pursued as means to enhance mobility. Substantial reduction in fuel consumption can potentially be achieved through advanced engine control, stored-energy capabilities, and energy regeneration. In coordination with other government agencies, including DARPA and the Navy, several electric drive technologies are being leveraged for Army combat vehicle application. In particular, the DARPA–Army joint program CHPS will demonstrate in a SIL an integrated combat power system in 2000.

WHEELED VEHICLE MOBILITY TD (2002). This TD will integrate an intelligent traction and steering controller with active suspension and electric drive systems to improve wheeled combat vehicle performance and evaluate differential torque steering and soft-soil mobility capabilities for application to high-capacity, high-mobility wheeled combat vehicles. The TD will be available for FCS.

d *Vehicle Electronics (Vetronics)*

Combat vehicles have evolved from simple mechanical weapon-carrying platforms that appeared during World War I to today's sophisticated electronics-intense weapon systems. Changes in the battlefield environment in terms of lethality and OPTEMPO have resulted in the need for continuous improvements in basic combat vehicle capabilities of lethality, mobility, C^3, survivability, and maintainability. The number, type, rate of change, and interdependency of requirements for increased performance, precision, and operational capability is rapidly increasing the complexity and electronic dimension of the total system. This also impacts the technological drivers of the system (Figure III–13). The traditional technological drivers (space, weight, thermal, etc.) are a result of machine-to-environment interactions and continue to play an important role. However, the interactions of machine-to-machine and crew-to-machine now have a sig-

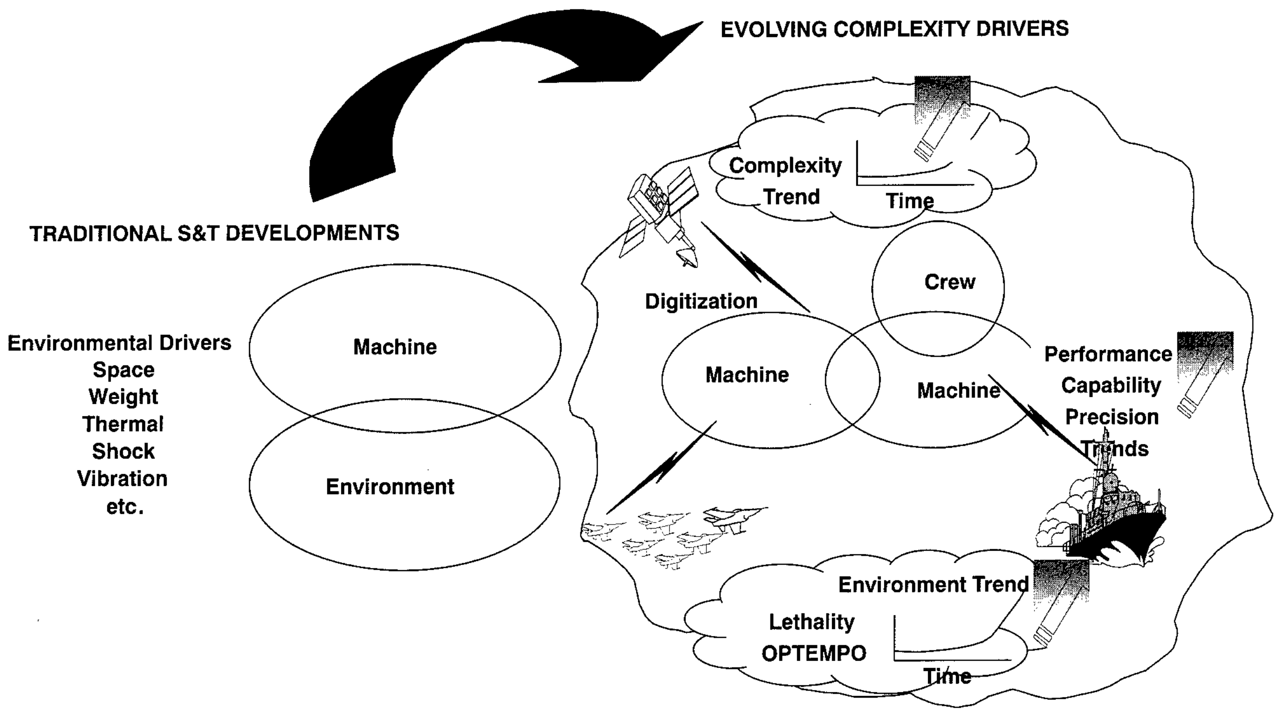


FIGURE III–13. EVOLVING COMPLEXITY OF WEAPON SYSTEMS

nificant impact on system performance and capability. These interactions necessitate a change to the traditional weapon system technology focus and development paradigm.

The vetronics concept has been defined to characterize and focus the technology made relevant by the system reliance on machine-to-machine interactions and crew-to-machine interactions. The traditional approach in combat vehicle development was to focus technology and a resulting subsystem on a given operational capability. This resulted in standalone subsystems; that is, they were self-contained and generally only required electrical power to operate. They had their own controls and displays, power conditioning, logic, feedback loops, etc. This also resulted in stovepipe technology development that resulted in a standalone look at technology drivers. This approach fails to identify and capture the entire impact of the technology drivers resulting from machine-to-machine and crew-to-machine interactions. The most basic vetronics concept, from an engineering model standpoint, is defined as a crew-centric and focuses on machine-to-machine and crew-to-machine interactions for military ground vehicles). Its fundamental purpose is to provide the necessary crew and machine capability fusion to enable and enhance the following objectives: system performance (or decreasing task execution timelines), cross-functional synergies (i.e., fire on the move), intelligence and automation, and implementation efficiencies. Historically, this has resulted in a technological focus on hardware and software architecture and integrated and multifunction crew stations. However, it could result in a focus on any technology where a crew-centric or global perspective would enable the above objectives. Robotics and embedded simulation are emerging focus areas.

CREW INTEGRATION AND AUTOMATION TESTBED (CAT) ATD (2000–04). This ATD will demonstrate the crew interfaces, automation, and integration technologies required to operate and support future combat vehicles. It will produce multimission crewstations that will cover 100 percent of the fight, scout, and carrier applications as well as embedded control UAVs and UGVs. These technologies and crew stations will be sized to meet the C–130 transportability requirements of

the FCS program. MANPRINT issues will be addressed through human factors modeling and analysis early on and through soldier and system performance measurement during experimentation. Testing, demonstration, and validation of the advanced architecture and crew station technologies will be performed in a SIL prior to integration on the vehicle platform for warfighter experiments (Figure III–14).

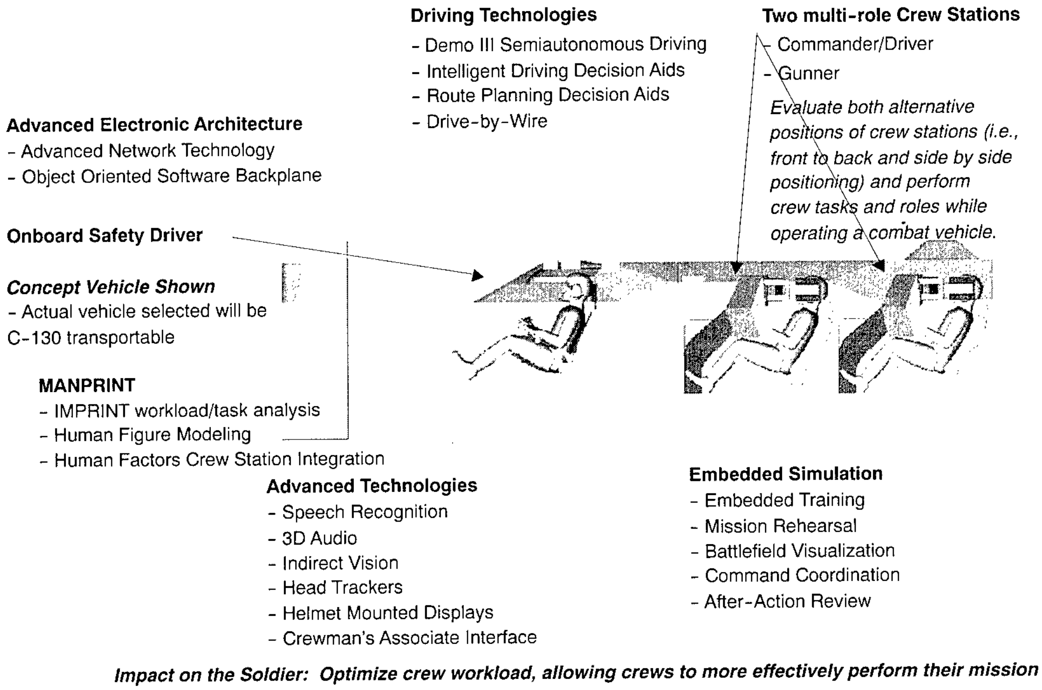


FIGURE III–14. CREW INTEGRATION AND AUTOMATION TESTBED (CAT) ATD

MULTIFUNCTION STARING SENSOR SUITE ATD (1998–03). This ATD will demonstrate a modular, reconfigurable, multifunction staring sensor suite using sensor fusion and multiple advanced sensor components, including staring dual-band IR arrays, eyesafe laser rangefinder, range mapper, aided target recognition algorithms, and acoustic arrays. (See Section III–E, "ISR&EW," for more detailed information.)

e *Robotic Vehicles*

Two key robotic vehicle programs are underway that will provide autonomous mobility technologies to both manned and unmanned vehicle systems, current and future. Autonomous mobility technologies can aid in driving functions of a manned vehicle, thus making it possible to remove a crew member to achieve a lighter, smaller, and more deployable and survivable system. These same autonomous driving technologies can also free the soldier from full-time remote control or teleoperation and allow him to perform other duties. This capability will greatly multiply the effectiveness of UGVs, which will then remove the operator from hazardous missions. Several UGVs could perform multiple assignments under the management of one operator.

DEMONSTRATION III EXPERIMENTAL UNMANNED VEHICLE TD (1998–02). This joint robotics TD seeks to develop a small, survivable UGV capable of autonomous operation over rugged terrain. This implies a vehicle weighing approximately 2,500 lb, able to maneuver cross-country at speeds of

up to 20 mph during daylight and 10 mph during darkness, and up to 40 mph on roads during daylight, permitting it to operate with a mixed maneuver force during tactical operations.

ROBOTIC FOLLOWER ATD (2000–05). This ATD is a core S&T objective of the Army, which will develop, integrate, and demonstrate the technology required to achieve unmanned follower capabilities for future land combat vehicles (e.g., FCS). This technology will support a wide variety of FCS/Objective Force applications such as Ruck Carrier, Supply Platoon, and Non- and Beyond-line-of-Sight Fire and Rear Security. The program leverages prior technology achievements in the areas of autonomous mobility, architecture, and sensor and robotics system integration. It will advance the state of the art in these areas and field demonstrate the technologies. This effort is focused on a series of demonstrations that will successively increase the follower performance and improve the maturity of the software algorithms, the software maturity index, and sensor technology for transition to the FCS program. This ATD compliments higher risk robotic efforts under development at DARPA.

SECOND-GENERATION ROBOTIC TD (2010–14). This unmanned system technology demonstration will take advantage of advanced processing, intelligent agents, low-observable technology, and sensor fusion to provide future forces with increased operational capabilities. Robotic vehicles will sense and comprehend their environment to aid in autonomous route navigation and detection avoidance to enable independent operations to complete a variety of missions.

3 Roadmap

The roadmap in Figure III–15 portrays the progression of the Ground Combat and Tactical Systems program to include system upgrades, advanced concepts, TDs, and ATDs.

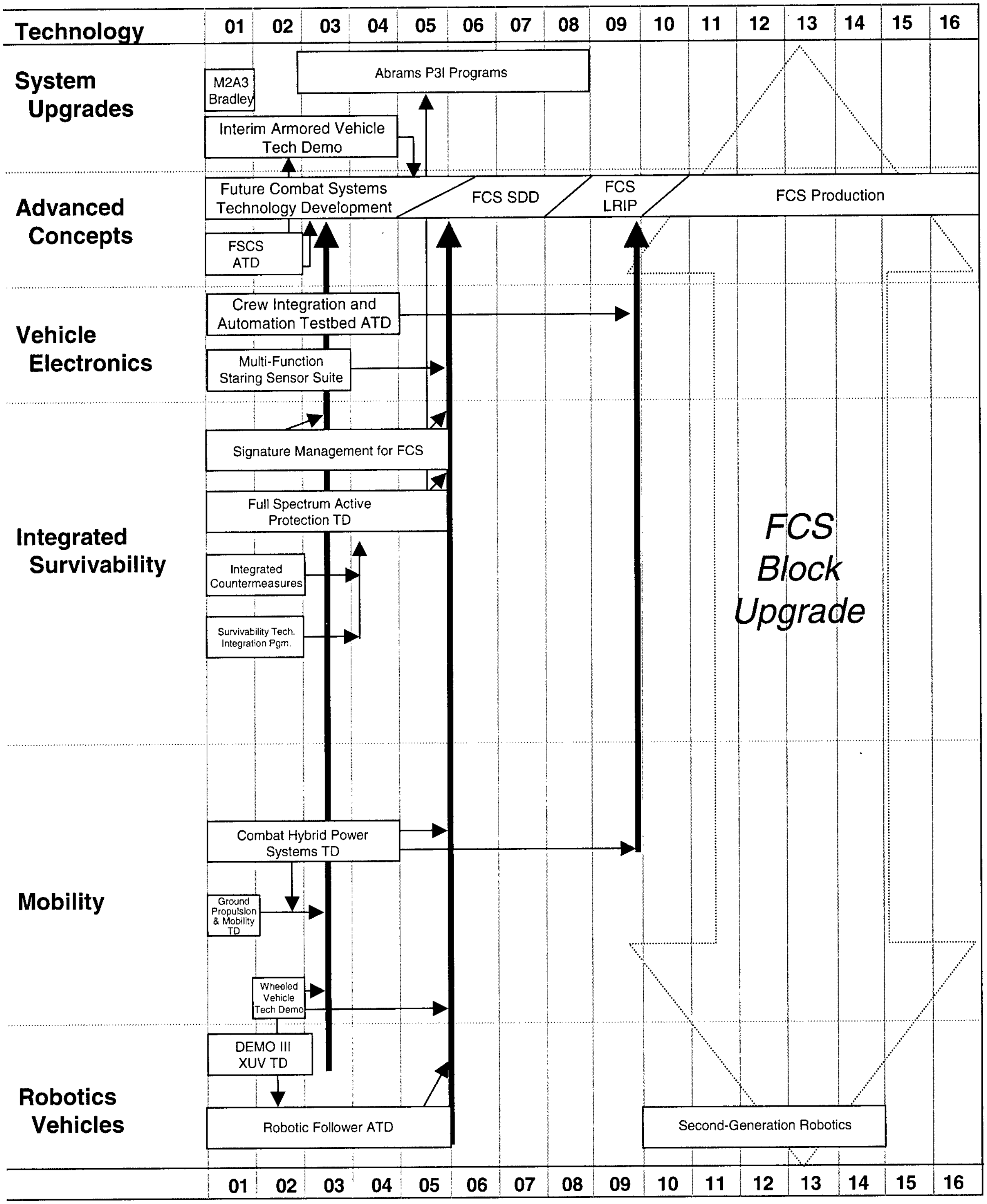


FIGURE III–15. ROADMAP—GROUND COMBAT AND TACTICAL SYSTEMS

G WEAPONS

The Weapons technology area develops armaments for all new and upgraded weapons systems. It includes efforts directed specifically toward armament systems, missiles systems, precision munitions, their components and launching systems, mortars, and area denial systems.

The challenge is to develop and demonstrate an unparalleled lethality capability that will provide lightweight air-deployable FCS with a lethal response capability against the full spectrum of threats at line-of-sight (LOS), non-line-of-sight (NLOS), and extended ranges well beyond LOS (BLOS). It will also develop unmanned systems that will provide situational awareness and potentially lethal capabilities.

The Weapons technology area strongly supports the needs of the Army in both tactical and strategic mission areas. It responds to the Army's operational needs for cost-effective system upgrades and next-generation systems in support of the seven Objective Force characteristics. Performance objectives focus on projecting lethal or nonlethal force precisely against an enemy without friendly casualties and collateral damage. General goals address the need for affordable all-weather, day, and night precision strike against critical mobile and fixed targets; defense against aircraft, ballistic missiles, and low-observable cruise missiles; gun and missile systems for advanced lighter-weight air or land combat vehicles and vehicle self-defense systems; lightweight, high-performance gun systems for artillery applications; and precise lethal force projection.

1 Modernization Strategy

The goal of the Weapons program in the areas of maneuver and fire support is to provide the Objective Force with a rapid or deployable dominance capability against the full spectrum of threat. Of most critical importance is to develop critical technologies that enable the Objective Force weapon systems and munitions to be smaller, lighter, and more affordable while providing overwhelming versatile lethality effects and precision delivery at extended ranges (0–50 km). These systems provide significant warfighter benefit as they maximize the user's mission flexibility and OPTEMPO, enhance force survivability through early attack and higher first-round hit and kill in smaller calibers, and dramatically reduce the logistics footprint of the Objective Force.

Weapons technologies and fire support development are critical to success on the future distributed battlefield. Modernization in these areas is essential for the Army to achieve the capabilities for the Objective Force. These programs will focus on system upgrades, new systems (FCS), and advanced concepts (Table III–7) that will provide quality materiel to commanders and ensure their ability to apply cutting-edge firepower in the 21st century.

TABLE III–7. WEAPONS DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Guns	**Guns**	Counteractive Protection Systems Third-Generation Radio Frequency Countermeasures (STO)
Future Combat Systems Multirole Armament & Ammunition	Responsive Accurate Mission Module (STO)	**Ordnance**
Objective Crew-Served Weapon	Objective Individual Combat Weapon System Enhancements (STO)	Tank Extended-Range Munition (STO)
Missiles	**Missiles**	Area Denial Systems (STO)
Low-Cost Precision Kill 2.75-Inch Guided Rocket	Beyond-Line-of-Sight Networked Fires Weapon	Advanced Light Armament for Combat Vehicles (STO)
Ordnance	Modernized Hellfire/Common Missile (STO)	Target Destruct (STO)
Direct Fire Lethality		
Precision-Guided Mortar Munition		

The objective of the 6.3 advanced technology development programs discussed in this section is to demonstrate affordable, smaller, or lighter advanced weapons and munitions technologies that will increase battlefield lethality and survivability for the Objective Force and the Future Combat Systems. This section describes several direct and indirect fire weapon demonstrations focusing primarily on the Objective Force and FCS, which may also provide recapitalization options for legacy systems. Specific advanced technology demonstrations include the Multirole Armament and Ammunition ATD (Figures III–16, III–17, and III–18), which provides a lightweight (C–130 air-deployable) single-armament cannon configuration for both maneuver and fire support roles, along with an ammunition suite and advanced warheads for overwhelming lethality out to 50 km with greater precision and accuracy.

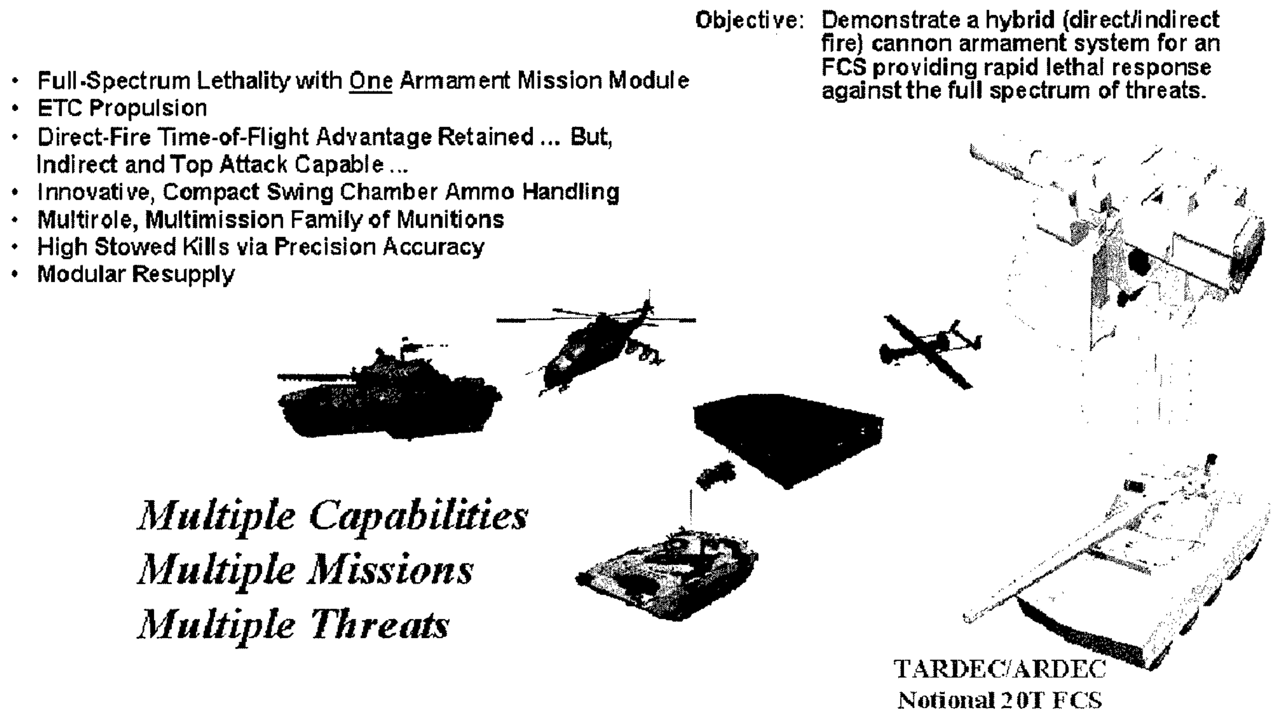


FIGURE III–16. MULTIROLE ARMAMENT AND AMMUNITION ATD—ARMAMENT DEVELOPMENT

Objective: **Develop and demonstrate an ammunition suite that provides FCS with the lethal response against the spectrum of threats at LOS, extended LOS, and BLOS engagements (0-50 km).**

- **Multirole, Multimission Munition Family**
  - ***Advanced KE:*** Defeats Future Heavy Armor Threats (LOS 0-4 km)
  - ***FCS MP-ERM***: Defeats High Value Point Targets (LOS/BLOS 2-10 km)
  - ***Smart Cargo***: High Accuracy Delivery of Lethal Payloads (BLOS 2-50 km)
- **Multipurpose Warhead Development**
  - Small, Lightweight and More Lethal
  - Advanced Explosives Development

    ... More Energetic, Less Sensitive...
- **Delivers Advanced Lethality for DARPA Demonstration**

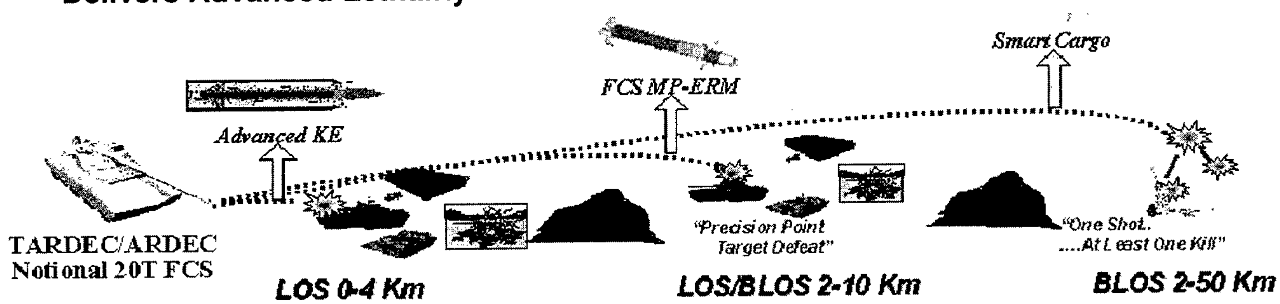


FIGURE III–17. MULTIROLE ARMAMENT AND AMMUNITION ATD—AMMUNITION SUITE DEVELOPMENT

Objective: **Develop and demonstrate smaller, lighter, more powerful multipurpose warheads utilizing advanced explosives (more energetic, less sensitive) providing FCS with the lethal response to defeat a full spectrum of threats.**

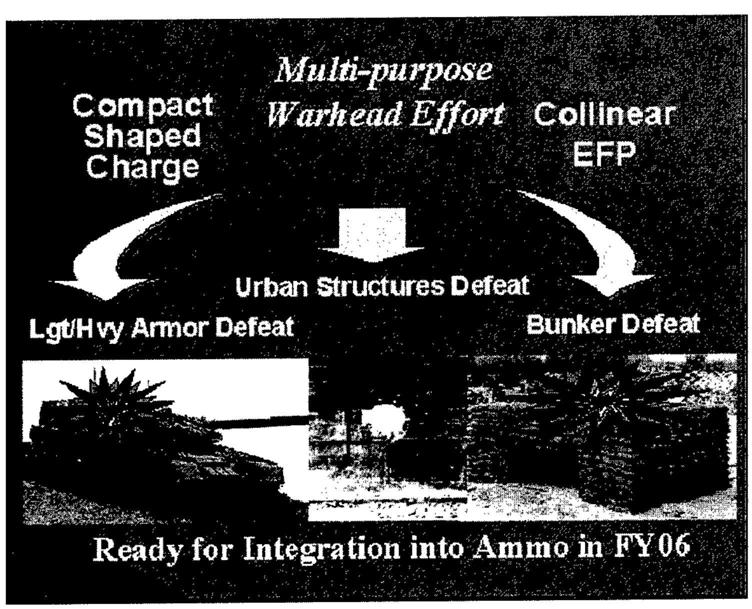


FIGURE III–18. MULTIROLE ARMAMENT AND AMMUNITION ATD—MULTIPURPOSE WARHEAD DEVELOPMENT

The Objective-Crew-Served Weapon (OCSW) will demonstrate a lightweight (38 lb) 25-mm weapon system with overwhelming lethality out to ranges approaching 2 km. The Low-Cost Precision Kill 2.75-Inch Guided Rocket will provide a 6-km standoff range precision strike capability against soft point targets. The Direct Fire Lethality (DFL) program will demonstrate novel KE-penetrator defeat of explosively reactive armor (ERA). The Precision-Guided Mortar Munition (PGMM) will demonstrate the capability to defeat a laser-designated point target at a range of 12 km. Other technology demonstrations include the responsive accurate mission module (RAMM), which will demonstrate an unmanned mortar armament capable of conducting multiple engagements; enhancements to the Objective Individual Combat Weapon (OICW); the Modernized Hellfire/Common Missile program, which addresses seeker and propulsion technology improvements; the Counteractive Protection Systems Third-Generation RF Countermeasures, which will provide countermeasures to defeat active protection systems (APSs); the Tank-Extended Range Munition (TERM), which will acquire and engage high-value targets beyond 8 km in both LOS and NLOS modes; and Area Denial Systems (ADS), which will demonstrate ground-based munition system concepts that will offer FCS the ability to shape the battlespace. In the area of combat vehicle antiarmor munitions, advanced shaped charges, and explosively formed penetrator (EFP) warheads will exploit technologies in explosives, liner materials, and modeling and demonstrate increased armor penetration through advanced warhead concepts. Advanced explosives will be scaled up and demonstrated for performance and tested for insensitive munition compliance using state-of-the-art warhead systems.

2 System Demonstrations

The Weapons technology subareas are Guns, Missiles, and Ordnance.

a *Guns*

The Guns subarea develops both conventional and electric gun technologies for all new and upgraded gun systems (lightweight ground combat, mortars, and small arms). It includes efforts directed toward future "generic" applied research and system technologies for small, medium, and large calibers, including barrel/launcher, ammunition/projectile, power supply and conditioning, weapon mechanism/ammunition feeder, propellants/ignition systems, and fire control.

MULTIROLE ARMAMENT AND AMMUNITION ATD (2000–07). The objective of this ATD is to develop and demonstrate a lightweight, multimission armament system and munition suite for the FCS. This effort will incorporate force-level trade studies, mission analysis, and demonstrators of major component technologies. A full-up integrated turret system (turret slew, gun elevation, and autoloader feed rate) and firing demonstration of ETC propulsion for KE projectiles will be conducted. The ATD includes development of an advanced lightweight cannon, autoloader, fire control, ETC propulsion, and turreted armament system. The munition suite will demonstrate an advanced KE design and initial multipurpose extended-range munition (MP–ERM) and Smart Cargo designs; and warhead development of a compact shaped-charge and GEN II/collinear EFP. *Supports:* FCS.

OBJECTIVE CREW-SERVED WEAPON (OCSW) ATD (2000–03). This ATD will demonstrate a lightweight, truly two-man-portable (<38 lb), crew-served, 25-mm weapon system with overwhelming lethality at extended range (up to 2,000 m) and capability to defeat protected personnel, defilade targets, and light armor. OCSW will be a more effective replacement for selected MK19/M2/M240 machine guns in dismounted and secondary armament roles. In FY01, demonstration of airbursting capability using an integrated full-solution fire control will be conducted. In FY02,

operational utility, technological maturity, and achievement of all exit criteria will be demonstrated. *Supports:* PM–Small Arms, future small arms weapon programs. *Transitions to:* PM Small Arms for SDD in FY04.

RESPONSIVE ACCURATE MUNITION MODULE (RAMM) STO (2001–05). The objective of the advanced development (6.3) portion of this STO is to provide a RAMM demonstrator capable of conducting multiple engagements, with backup manned semiautomated operation capability as well. RAMM will use a mortar armament in a mission module designed to be integrated into the Robotic Follower ATD to provide mobile, indirect fire system capabilities for FCS. RAMM will have the ability to know its orientation and track position with the movement of the Robotic Follower, receive digital coordinates of a target from the enhanced combat center or a forward observer, perform the ballistic computation with meteorological compensation, point the gun, and automatically load and fire 12 rounds/minute with 360-degree traverse capability. RAMM will be a precision first-round-on-target mortar system and provide unique operation utility in noncontiguous combat, rapid force projection, rear area combat support, and manned or unmanned operation. It also will be used as a force multiplier and as a possible alternative to antipersonnel mines with near immediate highly accurate response to call for fires. RAMM fabrication will start in FY03, culminating in a battlefield performance analysis. Fabrication and subsystem testing will be completed by the end of FY04. In FY05, final software will be completed, as well as integration into a suitable carrier. The effort will conclude with a full-scale demonstration. *Supports:* FCS.

OBJECTIVE INDIVIDUAL COMBAT WEAPON (OICW) SYSTEM ENHANCEMENTS STO (2000–03). This program provides improvements to enhance OICW system effectiveness and maintain Objective Force battlefield superiority. Demonstration of a gun-launched safe and arm microelectromechanical system (MEMS)/microenergetic initiation for 75 percent volume and 50 percent cost reduction will be conducted in FY01, followed by a demonstration of directed airburst and laser-steering and target tracking breadboard technology for improved ranging accuracy in FY02. The conclusion of this STO will demonstrate an incapacitation probability >50 percent against targets at 500 m in FY03. *Supports:* PM–Small Arms, future small arms programs. *Transitions to:* Small Arms for SDD in FY05.

b *Missiles*

In order to achieve the goals of the Objective Force, the Missile subarea must focus its technologies on enhancing Army transformation by providing the warfighter with affordable weapons that are lighter, smaller, and more accurate, but that still maintain overmatching lethality. This subarea is providing a low-cost, 2.75-inch guided rocket with an improved standoff range and precision kill capability, a common missile, and an improved counteractive protection system for RF countermeasures.

BEYOND-LINE-OF-SIGHT NETWORKED FIRES WEAPON (NETFIRES) TD (2001–04). This effort will design, develop, and demonstrate a platform-independent, container-launcher system and two NetFires missile variants to be launched from the container. The program is managed by DARPA and is jointly funded by the Army and DARPA. The NetFires demonstration is one of the primary thrusts under the Army's FCS effort to achieve transformation to a lighter, more agile, more lethal force. The container–launcher being demonstrated will be capable of housing 15 missiles and performing self-surveys. Calls for fire will be passed to the container–launcher via radio. The two missile variants being demonstrated are the Precision Attack Missile (PAM) and the Loitering Attack Missile (LAM). The objective length for both missiles is 55 inches with a diameter

of 7 inches. The PAM will use a controllable-thrust pintle motor, an uncooled imaging infrared seeker, and a semiactive laser. The objective range is between 20–30 km. The LAM will use a turbojet engine and a laser radar (LADAR) seeker and will have an objective range of 100 km with a 30–45 minute loiter time. Both missiles will utilize GPS/INS navigation, lock-on after launch, a two-way datalink, and onboard automatic target recognition. The demonstration is scheduled for FY01–04 and will culminate with guided test flights of both types of missiles launched from the container–launcher box. The Army is supporting the NetFires demonstration with the 6.3 programs discussed in this section and the 6.2 programs discussed in Section IV–G, "Weapons."

LOW-COST PRECISION KILL (LCPK) 2.75-INCH GUIDED ROCKET ATD (1999–03). This effort will demonstrate a low-cost (<$10,000), accurate (~1 m CEP), 2.75-inch guided rocket that provides a standoff range (6 km) surgical strike capability against specified soft point targets. Utilizing a small, strapdown laser seeker, off-the-shelf inertial devices and a low-cost control mechanization, a high single-shot probability of kill will be achieved, reducing cost/kill by 2X–4X, minimizing collateral damage, and increasing the number of stowed kill by 4X–20X. *Supports:* AH–64D Apache, RAH–66 Comanche. *Transitions to*: SDD in FY04.

MODERNIZED HELLFIRE/COMMON MISSILE (MODHF/CM) STO (1999–03). This effort will address seeker and propulsion technologies, incorporating multimode applications (i.e., ground-to-ground missions in support of Common Missile as well as the traditional Hellfire/Longbow air-to-ground missions). The ModHF program will leverage missile technology being developed in support of the NetFires effort and supports the Army vision of lighter, more lethal weapon systems contained on the FCS and Common Missile. The development of the technologies in this program and associated system integration efforts are part of a joint AMRDEC/PEO Tactical Missile ModHF/CM program designed to achieve Milestone B decision based on the new acquisition methodology, simulation-based acquisition. *Supports:* Hellfire, NetFires, Common Missile, RAH–66 Comanche, AH–64D Apache.

COUNTERACTIVE PROTECTION SYSTEMS (CAPS) THIRD-GENERATION RADIO FREQUENCY COUNTERMEASURES STO (2000–03). This effort will demonstrate, in missile flight tests, countermeasures that can defeat current and future threat APSs in 95 percent of engagements. *Supports:* PEO Tactical Missiles, current and future antiarmor weapon systems. *Transitions to*: the PMs of Javelin, CCAWS (TOW F&F), and AGMS (Hellfire) for SDD in FY03.

c *Ordnance*

The Ordnance subarea develops munitions, projectiles, fuzes, explosives, and novel concepts for conventional warheads and penetrators for antiair/antisurface warfare. It includes efforts directed specifically toward advanced warhead and penetrator concepts, advanced kill mechanisms employing multioption warheads, new warhead materials, advanced gun propellants, material processing techniques, analytical design tools, advanced explosives, advanced sensors, signal processing algorithms, guidance integrated fuzing, GPS miniaturized solid-state components, countermeasure resistance, electronic safe and arm, reliability, and affordability.

DIRECT-FIRE LETHALITY (DFL) ATD (2000–01). The objective of this ATD is to demonstrate, using novel penetrators and miniature radial thrusters, an integrated 120-mm advanced KE cartridge that will defeat the 2005 ERA projected threat with up to a 70 percent increase in lethality over the M829A2 and a 30–70 percent increase in system accuracy under stationary conditions over the M829A2/M1A2. *Supports:* The development of an advanced KE-cartridge for the ammunition suite for the Multirole Armament and Ammunition ATD in FY02.

PRECISION-GUIDED MORTAR MUNITION (PGMM) ATD (2000–01). This ATD will demonstrate the capability to defeat a point target at extended ranges with a 120-mm mortar munition. The demonstration will consist of hitting a laser-designated bunker at a range in excess of 12 km with a mortar round that integrates strapdown gyros and a laser seeker with a maneuverable airframe fired from a 120-mm mortar tube. *Supports:* PM–Mortars and future precision-guided mortar efforts.

TANK EXTENDED-RANGE MUNITION (TERM) STO (2000–01). TERM will expand the Abrams tank battlespace by engaging high-value targets beyond 8 km in both LOS and NLOS modes. Intended high-value targets will include battle command vehicles, reconnaissance vehicles, and armored vehicles equipped with ERA and APSs. In FY01 and FY02, candidates will demonstrate their sensor system's ability to acquire stationary and moving targets. They will also demonstrate other aspects of their design such as lethal mechanism penetration against range targets, airframe structural integrity, and aerodynamic performance. *Supports:* Development of a MP–ERM projectile for the FCS Multirole Armament and Ammunition ATD in FY02. *Transitions to:* PM–TMAS for program definition risk reduction in FY02.

AREA DENIAL SYSTEMS (ADS) STO (2000–01). This program will offer FCS the ability to shape the battlespace and protect its flanks with a munition system that is more logistically efficient than current systems. The objective is to reduce the number of ground-based munitions required by a factor of four, while keeping unit costs low ($2,000–$3,000) and the size small (4–5-inch diameter). In FY00–01, concepts for traversing and side-attack munition, advanced queuing and tracking sensor, and more efficient and compact EFP warheads will be evaluated, and brassboard components demonstrated. *Supports:* FCS. *Transitions to:* Next generation of scatterable munitions and Raptor in FY02.

ADVANCED LIGHT ARMAMENTS FOR COMBAT VEHICLES (ALACV) STO (2000–03). The objective of this effort is to design, develop, and demonstrate, by the end of FY03, optimum ammunition components in bursting munitions and novel KE long rods for 40-mm applications that would provide enhanced antiarmor and antipersonnel effects for ground combat vehicles. Bursting ammunition enhancements will focus on development, test, and evaluation of advanced fuzing and warhead lethality. KE ammunition enhancements will focus on leveraging large-caliber novel penetrator concept evolution for defeat of applique-protected targets and increasing behind-armor effects. *Supports and transitions to:* FCS.

TARGET DESTRUCT STO (2000–01). This program will demonstrate the most promising advanced cannon and medium-caliber penetrators and warheads at ordnance and "super ordnance" velocities at extended ranges with up to 75 percent increase in lethality over the current fielded equivalent caliber of ammunitions. In FY01, demonstrations will also be conducted on novel penetrators/warheads with 25 percent more lethality than equal weight, conventional penetrators used in advanced kinetic-energy missiles, line-of-sight antitank P^3I, and compact kinetic-energy missiles. *Supports:* PEO–GCSS, FCS.

3 Roadmap

The roadmap for Weapons is shown in Figure III–19.

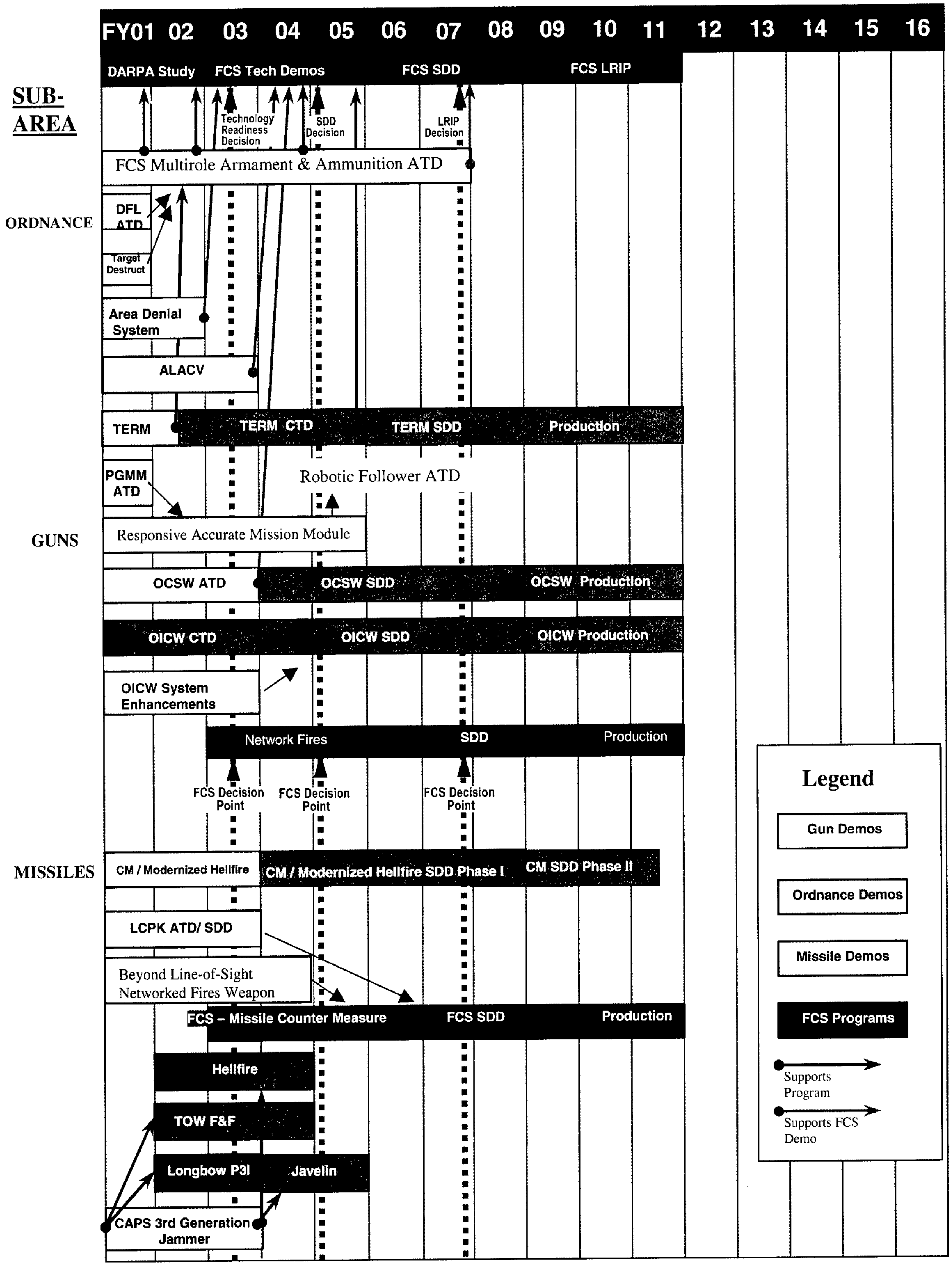


FIGURE III–19. ROADMAP—WEAPONS

H SOLDIER SYSTEMS

The Army soldier transformation effort is a comprehensive, multifaceted program designed to maximize the operational capabilities of the soldier as a "system." The soldier system is defined as the individual soldier and everything he/she wears, consumes, or carries for individual use in a tactical environment. Continuous technology advances in individual and crew operational effectiveness, command and control, tactical mobility, intelligence capabilities, and survivability will enable full-spectrum dominance at the individual level.

The system approach to modernizing the soldier is focused on optimizing the soldier's effectiveness through (1) the synergy that results from effective integration of technologies at the system level, and (2) the proper integration of soldier systems across the full spectrum of operations and operating environments. Using this approach, the future soldier platform has a firm foundation, wherein the soldier is the focal point of a revolutionary vision. Additionally, the benefits derived from applying a system approach to soldier developments will result in accelerated product development cycles, lowered acquisition costs, and reductions in size, weight, and power requirements

1 Modernization Strategy

The Army strategy is to field a force that is responsive, deployable, agile, versatile, lethal, survivable, sustainable, and dominant at every point along the spectrum of operations, anywhere in the world. These forces need to be more survivable. For individual soldiers that means lighter and tougher body armor. The lethality, predictability, flexibility, capability, and "smartness" of a lightweight soldier system are critical to DoD's future warfighting and peacekeeping capabilities. Soldier Systems technologies will aggressively address these issues, including reducing the logistics footprint and replenishment demand. Future warriors in the Objective Force will meet these challenges with the technologies discussed in this section.

The warrior systems modernization strategy (WSMS) is an approach to integrated program planning that connects the entire Army's R&D investment (including DARPA leveraging) related to soldier/warrior systems across all phases of the R&D life cycle. The programs that are part of this effort cover the full range of the five major soldier/warrior system domains: lethality, survivability, mobility, sustainability, and C^4I. Also included are the modeling and simulation, human science, and MANPRINT efforts that support the warrior systems development. WSMS consists of a comprehensive database that uses the hypertext format to show all possible linkages among S&T and SDD efforts. Users of the database have access through the worldwide web (web).

Chemical/Biological Defense efforts related to the soldier system are presented in Section III–J as well as in Section III–I, "Biomedical."

Table III–8 presents the demonstrations and systems that are part of the soldier systems modernization roadmap.

TABLE III–8. SOLDIER SYSTEMS DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Lethality Objective Crew-Served Weapon **Survivability** Objective Force Warrior (STO)	**Lethality** Objective Individual Combat Weapon System Enhancements (STO) **Mobility** Precision Roll-On/Roll-Off Air Delivery (STO)	**Sustainability** Combat Rations for Enhanced Warfighter Logistics (STO) Reforming Diesel (Cogeneration) (STO)
Advanced Concept Technology Demonstration		
C⁴I Military Operations on Urbanized Terrain		

System/System Upgrade/Advanced Concept	
System Land Warrior Army Field Feeding Future Objective Family of Small Arms Air Delivery Systems	**System Upgrade** Objective Individual Combat Weapon System Enhancements Objective Crew-Served Weapon Future Warrior Technology Integration **Advanced Concepts** Light Fighter Lethality

2 System Demonstrations

The Soldier Systems is an integrated system-of-systems that includes the individual soldier and everything worn, consumed, or carried for individual use in a tactical environment. The Soldier Systems technology subareas are Lethality, Survivability, Mobility, Sustainability, and C^4I.

a *Lethality*

Lethality includes the soldier's ability to detect, recognize, and destroy enemy targets. Every element in the warfighting formation must be capable of generating combat power and contributing decisively to the conflict. Elements of lethal combat power are fire, maneuver, leadership, and protection. Lethality systems will enhance individual and crew combat weapons with improved effectiveness. The Objective Individual Combat Weapon (OICW), with its ongoing system enhancements, is the future individual lethality component of the soldier system. The Objective Crew-Served Weapon (OCSW) also provides lethality support for the soldier system. Both will provide the capability to attack defilade or NLOS targets and targets that have gone to ground. The Land Warrior (LW) capabilities will provide accurate, rapid, automated target handover to indirect fire support, enhancing the lethality of the total force. The Javelin system will interface with the LW capabilities to provide antitank lethality with significant weight reduction.

The lethality demonstrations (OICW System Enhancements and OCSW) will focus on weapons, munitions, and target detection and acquisition. See Section III–G, "Weapons," for a complete description.

b *Survivability*

Survivability is the ability to protect oneself against weapon impacts and environmental conditions. The survivability challenge is to enable warfighters—dismounted and vehicle crews—to function effectively and fully exploit weapon system capabilities despite battlespace, operational, and environmental hazards and enemy threats; they must be able to survive when the weapon system ceases to function. Survivability systems will integrate threat protection against ballistic, flame or thermal, chemical and biological, directed-energy, surveillance, and environ-

mental hazards. Keys to accomplishing this are to mitigate personal risk and to enhance the capabilities of individual warfighters. Combat identification (CID) capabilities will be integrated into soldier systems to minimize fratricide. Utilization of the digital net, coupled with inherent enhancements, will significantly improve the survivability of the individual soldier and the entire force through increased dispersion while maintaining a common picture of the battlespace.

OBJECTIVE FORCE WARRIOR ATD (2003–07). The DAS(R&T) recently established a Soldier System Independent Review Team (IRT) comprised of retired military and technical experts from industry, government, and academia. Their charter was to assess the ability of the current Warrior Technology S&T program to achieve revolutionary soldier system capability for the Objective Force. If program was deemed sufficient, the IRT also was to provide possible strategies to achieve that goal. Key findings by the IRT were that:

- Significant Objective Force warrior capabilities could not be realized within this decade with the current plan.
- More can be accomplished more quickly to enhance the capabilities of the Objective Force warrior.
- The current S&T program could yield revolutionary soldier performance within this decade if many of its efforts were redirected or better resourced.

The recommendations have been accepted, and the DAS(R&T) is refocusing the S&T soldier systems program to achieve revolutionary capabilities within the decade. Key investment areas include system-of-systems warrior designs, nanotechnologies for integrated armor, environment, and electrical clothing; innovative power generation technologies (leveraging DARPA Palm Power investment); robotic support and reconnaissance vehicles; novel chemical and biological soldier protection; very lightweight lethality; integrated signature management; and high-fidelity human engineering models. The S&T community is preparing a new action plan to provide the necessary program changes to meet the new program goal. The intended result is an affordable, integrated warrior system-of-systems that improves soldier lethality, survivability, mobility, adaptability, and extended field endurance within this decade.

c *Mobility*

Mobility is the capability to move about the battlespace while fully equipped to execute assigned missions. In the near term, reductions in weight coupled with better integration provides improved responsiveness and increased soldier agility. In the far term, combat load handling devices are anticipated that will reduce the combat load of the dismounted soldier. Enhancing dismounted operations in snow and ice and at night will also be addressed. Advanced mobility sensors, coupled with navigational aids (e.g., GPS, digital maps, overlays), greatly enhance the speed, accuracy, and maneuverability of the individual and unit.

Advanced airdrop (both personnel and cargo) technologies will enable rapid power projection through reduction of the logistical footprint and replenishment demands. Airdrop technology challenges include modeling transient parachute-opening processes; developing lower-cost, lighter-weight, and reduced-volume parachutes; advancement of nonparachute decelerator technologies for soft landing of personnel and sensitive equipment; and developing high-glide decelerators for precision airdrop applications.

Investigation and demonstration of systems of advanced technologies focus on substantially improving current capabilities across the spectrum of airdrop operations. Specific transitions

include precision-guided "smart" airdrop systems using both (1) high-glide-ratio, flexible-wing technology, and (2) advanced ballistic and semiballistic decelerators that result in greater payloads, offset distances, and accuracy; improved efficiencies in cost of delivery; enhanced survivability of delivery aircraft; and rapid deployment of equipment and personnel in the drop zone.

High-fidelity parachute and airdrop system design tools are currently lacking. Airdrop model tools are required to optimize parachute design and to reduce development time and costs. The modeling tools being developed will provide an integrated, full-function prediction and analytical capability for the Objective Force.

PRECISION ROLL-ON/ROLL-OFF AIR DELIVERY STO (2000–05). Advanced technologies for air delivery of cargo with precise accuracy over extended distances are needed. The objective of this effort is to investigate and demonstrate a system of advanced technologies focused on substantially improving current capabilities across the spectrum of airdrop operations. Technologies include advanced pneumatic muscle and airbag technologies to provide a roll-on/roll-off quick airdrop capability for heavy cargo; the use of air-inflated parafoils and 3D weaving techniques to provide a long-range, autonomous airdrop capability with the option to deliver separate and distinctive payloads to multiple locations; and controllable cluster parachutes for high-altitude, accurate (50–100-meter CEP) "just in time" delivery to provide low-cost precision resupply. Airdrop modeling tools will be developed and validated to optimize parachute designs and to reduce development time and costs. Precision roll-on/roll-off air delivery technologies significantly impact soldier mobility, survivability, and sustainability. *Supports:* Advanced airdrop development, engineering development, Affordable Precision Resupply Air Delivery System, Roll-On/Roll-Off Air Delivery System.

d *Sustainability*

Sustainability is the ability to maintain the force in a tactical environment. Sustainability systems will be adaptable to all levels of operations in the dynamic battlespace. This operational domain includes the tailoring of rations and field-feeding equipment to combat situations for improved mobility and sustainability. Features include fresh-like, shelf-stable ration components; nutritional tailoring to enhance mental and physical performance; resource-efficient, food-service equipment that improves quality of life for the soldier; and rations and equipment with reduced weight and volume. Achievements will be made through advances in food preservation, packaging, and food service equipment and energy technologies. Technologies pursued in this effort address the need to "fuel the fighter"—to deliver the right nutrients at the right levels, at the right time, and in the right combination; to provide rapidly deployable food service equipment in forward areas; and to provide versatile airdrop capabilities critical to worldwide force projection and resupply. To accomplish the goals of the Objective Force, the logistics footprint and replenishment requirements must be aggressively reduced through radical demand reductions across the force. This includes investing in a systems approach to the design of weapons and equipment and to revolutionizing the manner in which personnel and materiel are transported and sustained.

Ration development challenges include effectively applying innovative food formulations, processing, and packaging to produce fresh-like ration components that can be used worldwide under all environmental conditions and, as required, that provide enhanced mental and physical performance. Processing can lead to undesirable changes that are further compounded by lengthy, uncontrolled storage. Rations must be safe, nutritious, lightweight, low volume, air

droppable, easy to prepare, and highly acceptable, while meeting vigorous shelf life requirements.

The challenge to providing mobile field services for kitchens, sanitation, laundries, and space heating is the efficient cogeneration of heat and electric power by integrating fuel cells and thermophotovoltaic generators. Clean, reliable diesel combustion, efficient heat transfer, safe methods for storing perishable subsistence, and modularity and integration of components are needed to support transportable kitchens for all environmental extremes.

COMBAT RATIONS FOR ENHANCED WARFIGHTER LOGISTICS STO (2000–03). This effort develops a logistically focused ration system to improve future warrior performance, reduce food waste, and reduce the footprint. Lightweight, low-volume, fresh-like rations will increase acceptance and consumption of rations by 20 percent and reduce ration field waste by 20 to 30 percent. A ration selection module will be designed that considers nutritional and energy requirements, then specifies what food components are to be taken and when, optimizing soldier performance. *Supports:* Joint Service Food Program, Food Advanced Development.

REFORMING DIESEL (COGENERATION) STO (1998–01). Dual-use technology that integrates heat and electronic power to meet the energy requirements of heat-driven logistics systems, including kitchens, laundries, and showers is being developed. The cogenerator will be integrated into a field kitchen that will enable the preparation of high-quality meals efficiently (50 percent fuel reduction), quietly (10-dB noise reduction), and reliably (50 percent increase in MTBF. *Supports:* Joint Service Food Program, Food Advanced Development, Engineering Development–Military Subsistence Systems, Army Field Feeding Equipment 2000 (Mission Needs Statement).

e *Command, Control, Communications, Computers, and Intelligence*

C^4I is the soldier's ability to direct, coordinate, and control personnel, weapons, equipment, information, and procedures necessary to accomplish the mission. C^3 have combined-arms-compatible systems providing situational awareness. This awareness is supported by the aggregated capabilities of the soldier's radio and computer, integrated with digital head-mounted displays, CID, and navigation aids. Improvements will focus on individual communications, computer-aided control systems, navigation, information fusing and management, visual and aural enhancement (including image capture and transmission), and situational enhancement.

MILITARY OPERATIONS IN URBANIZED TERRAIN (MOUT) ACTD (1998–02). The MOUT ACTD is a joint (Army and Marine Corps) program that encompasses a wide range of technologies, including advanced technologies for the soldier system and other weapons platforms such as advanced individual precision weapons; CID; countersniper, nonlethal weapons; advanced sensors; situational awareness; and personal protection. The core capability that will be generated via the ACTD is a linkage of a series of advanced systems and components into a MOUT system-of-systems whereby the components are interfaced, integrated, or linked in an architecture to ensure their effective interoperability and functionality in the challenging MOUT environment. The integrated MOUT system-of-systems will provide a robust and enhanced joint operational capability encompassing the areas of urban C^4I, engagement, and force projection. *Supports:* Upgrades to LW.

3 Roadmap

Figure III–20 is the roadmap for the Soldier Systems area.

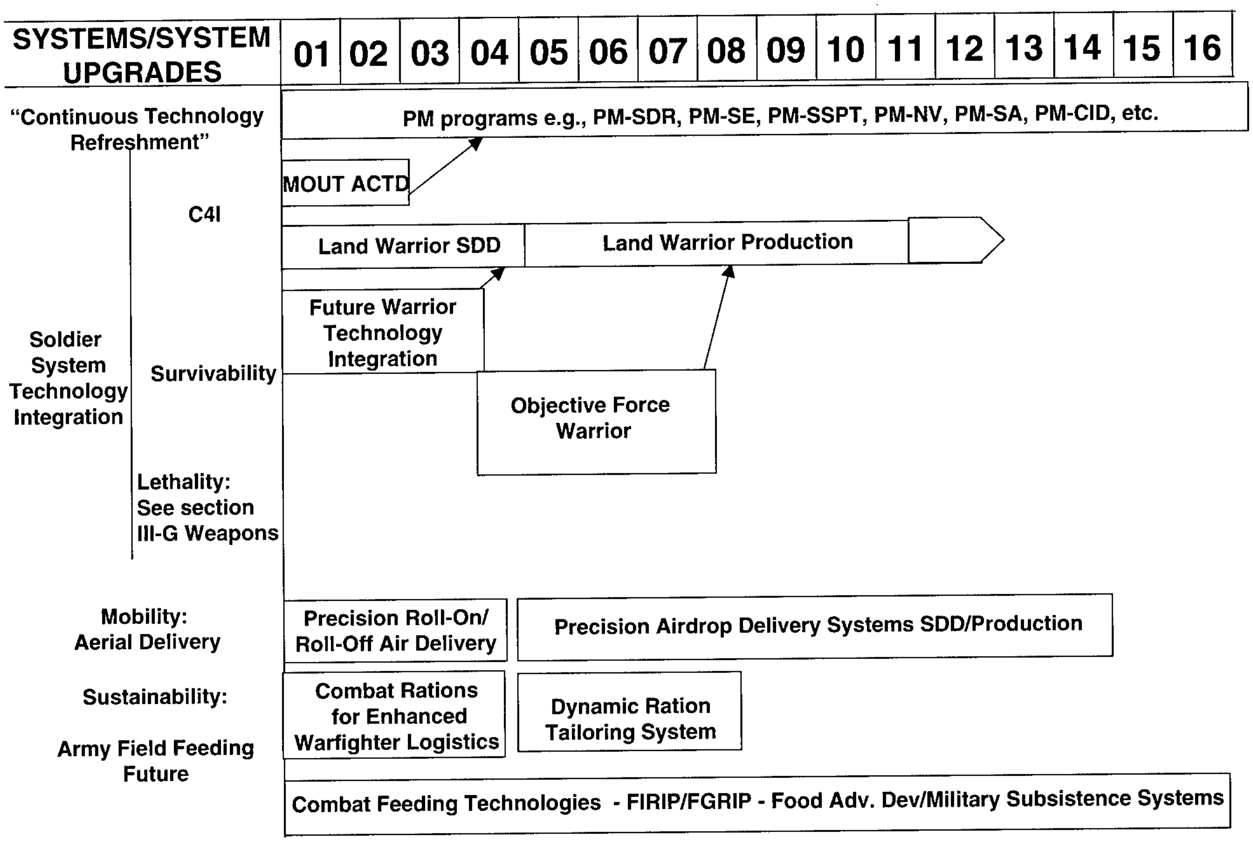


FIGURE III–20. ROADMAP—SOLDIER SYSTEMS

I BIOMEDICAL

The long-term transformation of the Army into the Objective Force will require changes in the way the Army organizes, mans, equips, trains, supports, and fights. An implicit requirement of this transformation is the full consideration of the capabilities and survivability of individual service men and women—the most important and most vulnerable components of military systems and mission capabilities.

U.S. forces must be capable of responding to missions anywhere in the world, across the full spectrum of conflict ranging from humanitarian assistance and disaster relief, to peacekeeping, to major theater wars with potential use of weapons of mass destruction. Future operational concepts increasingly rely on individual soldiers to execute missions of increasing diversity and complexity during continuous accelerated OPTEMPO over an expanded battlespace.

Survivability of the individual soldier requires optimization of their mental and physical performance and avoidance of system hazards while simultaneously protecting against enduring and significant threats to soldier health and performance posed by disease, extreme climates, operational stress, and battle injury. The medical logistics footprint must be reduced to achieve strategic responsiveness, but survivability cannot be compromised—delivery of emergency and essential healthcare with minimal logistics support will require new technologies and field medical procedures that allow soldiers to be treated successfully even with delayed access to physicians and surgical and hospital facilities.

Biomedical S&T addresses the full spectrum of these requirements (Figure III–21). Biomedical research provides vaccines, pretreatment drugs, diagnostics, and technology support for training and operational strategies that reduce or eliminate health hazards, maximizing the readiness of soldiers to deploy and fight. Biomedical research is vital to a full understanding of the human capability dimension, common to all joint warfighting capabilities. As such, it enables leaders to optimize warfighting capabilities across the continuum of conflict, including all mounted and dismounted forces. Biomedical research also provides medical devices, drugs, biologicals, and medical knowledge to optimize far-forward diagnostics and treatment capabilities of casualties (with enhanced mobility) that allows medical support capabilities to maintain an OPTEMPO consistent with the warfighter.

In addition to the overarching capabilities described above, biomedical research supports Future Combat Systems capabilities by developing technologies and biomedical knowledge to preserve and optimize the individual performance of soldiers. Anticipated payoffs from Biomedical S&T investments include:

- Ability to sustain operations over extended periods without risk of operator failure due to disease, chemical and biological warfare (CBW) threats, and physical or mental fatigue.
- Support to system safety for human operators through health risk identification, assessment, and mitigation strategies.
- Contributions to situational awareness through human health and performance monitoring.
- Improved survivability when hit through onboard first-response casualty care capabilities.

1 Modernization Strategy

The biomedical modernization strategy is focused on force preservation, expanding information dominance to include knowledge of the human dimension of the battlespace, and updating combat health support systems to enable continued support for the future battlefield. S&T efforts

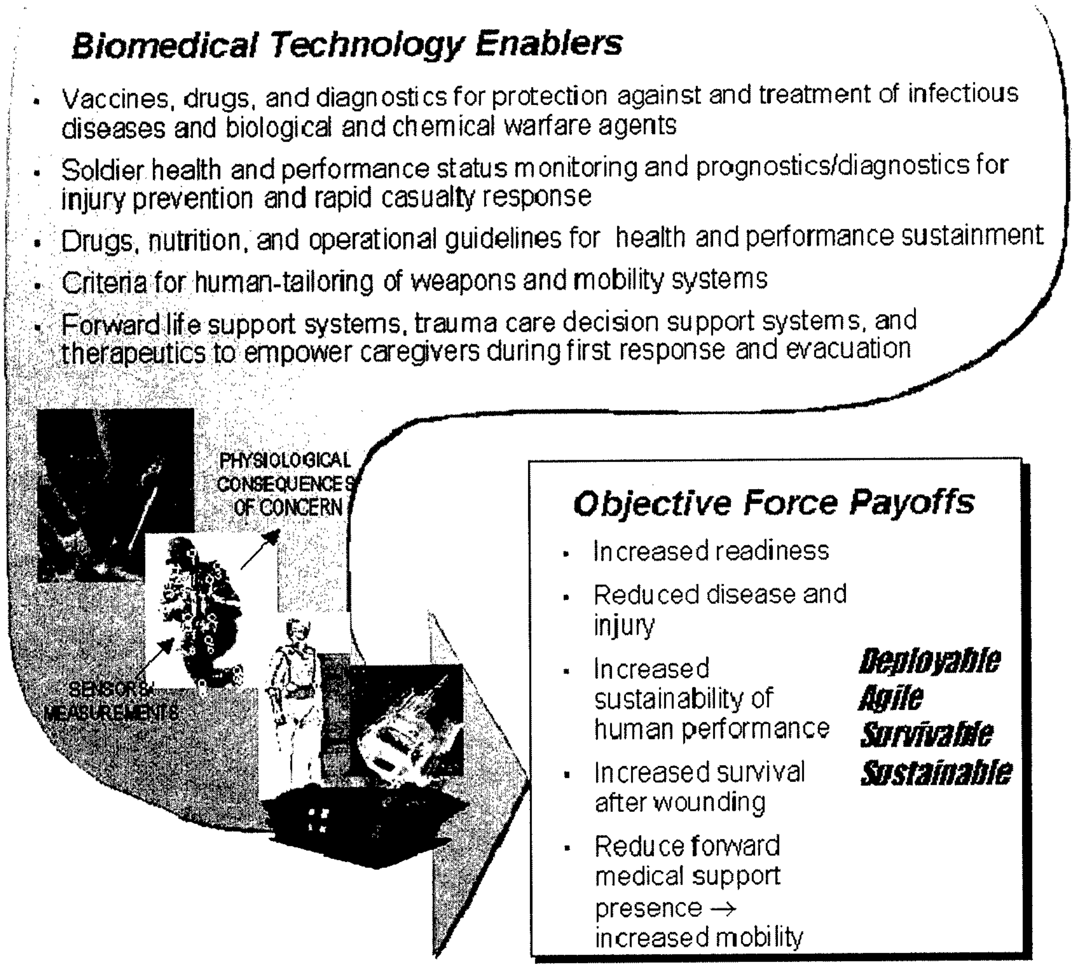


FIGURE III–21. BIOMEDICAL TECHNOLOGY: A KEY ENABLER OF THE OBJECTIVE FORCE

support the three pillars of force health protection: a healthy and fit force, casualty prevention, and casualty care management. A healthy and fit force will be promoted through development of biomedical knowledge-based guidelines to promote healthy behaviors and reduce injuries that occur during training. A major focus of casualty prevention is the development of vaccines and drugs to counter potential mission-aborting infectious diseases and eliminate or minimize death and injury caused by CBW agents. Drugs and biomedical knowledge-based strategies will also be identified to minimize adverse impacts of military operational stresses and systems hazards on soldier health and performance. The biomedical modernization strategy also includes the adaptation of sensor technologies and development of supporting algorithms and models to enable real-time health and performance monitoring for force optimization, injury prevention, and casualty management. Also in the area of casualty care management, drugs and biological products will be developed for self-aid, buddy-aid, and medic use to limit hemorrhage and reduce tissue damage subsequent to ballistic injury. Finally, the modernization strategy focuses on developing forward-deployable, transportable medical devices and supporting Class VIII medical supplies and guidelines for resuscitation, life support, and resuscitative surgery.

Table III–9 summarizes the technology demonstrations and systems, system upgrades, and advanced concepts listed in the biomedical modernization roadmaps (Section III–I.3). Unlike most nonmedical TDs, medical TDs must usually be conducted in a laboratory, rather than in the field, because of the regulatory requirements placed on medical materiel by the Department of Health and Human Services through the Food and Drug Administration (FDA). The FDA requires that medical products (e.g., vaccines, medical devices, drugs) demonstrate preclinical safety and efficacy prior to product evaluation in man. Thus, the medical system acquisition process has led to a tailored life-cycle system management model for medical materiel. The TD phase of the medical materiel life cycle allows technology candidates to be fully evaluated for preclinical safety and efficacy. When animal models are not available, limited clinical Phase 1 and 2 safety and efficacy studies or limited clinical challenge studies are also performed in the TD phase. The best candidates are then selected for transition to development. Descriptions of major TDs are provided on subsequent pages. Dates provided in the text reflect the timeline of the product from technology base research to development (Milestone B) or, in the case of information products, to direct fielding to the user community.

TABLE III–9. BIOMEDICAL DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
There are currently no Army Biomedical ATDs. **Advanced Concept Technology Demonstration** **Combat Casualty Care** Joint Medical Operations—Telemedicine	**Infectious Diseases of Military Importance** Drug for Prevention of Resistant Malaria Drug for Treatment of Resistant & Severe & Complicated Malaria (STO) Advanced Antimalarial Drugs Malaria Falciparum Vaccine (STO) Malaria Vivax Vaccine (STO) Combined Malaria Vaccine Antidiarrheal Disease Vaccines (STO) Oral Multidisease, Antidiarrheal Vaccine Dengue Vaccine (STO) Hantavirus Vaccines Meningococcal Vaccine Human Immunodeficiency Virus Vaccine Common Diagnostic Systems for Biological Threats & Endemic Infectious Diseases (shared demonstration) (STO) Advanced Diagnostics New Standard Insect Repellent (STO) Insect Vector Controls **Medical Chemical & Biological Defense** Common Diagnostic Systems for Biological Threats & Endemic Infectious Diseases (shared demonstration) (STO) Active Topical Skin Protectant Chemical Agent Prophylaxes Stage II Medical Countermeasures Against Vesicants Stage II Medical Countermeasures for *Yersinia pestis* Medical Countermeasures for Brucellosis	Medical Countermeasures for Encephalitis Viruses Medical Countermeasures for Filoviridae (STO) Medical Countermeasures for Orthopox Viruses (STO) Medical Countermeasures for Ricin Medical Countermeasures for Staphylococcal Enterotoxins Multiagent Vaccines for Biological Threat Agents (STO) **Military Operational Medicine** Continuous Operations & Fatigue Countermeasures (STO) Military Health Behaviors Promotion/Interventions Biomechanical Optimization (STO) Visual Performance Optimization (STO) Deployment Stress Models & Countermeasures Performance Limits in Environmental Extremes (STO) Warfighter Readiness & Sustainability (STO) Deployment Toxicology Assessment Methods (STO) Laser Bioeffects & Treatment (STO) Whole Body Blast Bioeffects/Blunt Trauma Injury Models Mechanical Stress & Crew Protection (STO) Head-Supported Mass: Warfighter Health & Performance (STO) **Combat Casualty Care** Blood Products (STO) Resuscitation (STO) Hemorrhage Control (STO) Warrior Medic & Medical/Surgical Devices (STO) Neuroprotection Dental Disease Reduction Advanced Trauma Patient Simulator (STO) Medical Modeling & Informatics

System/System Upgrade/Advanced Concept

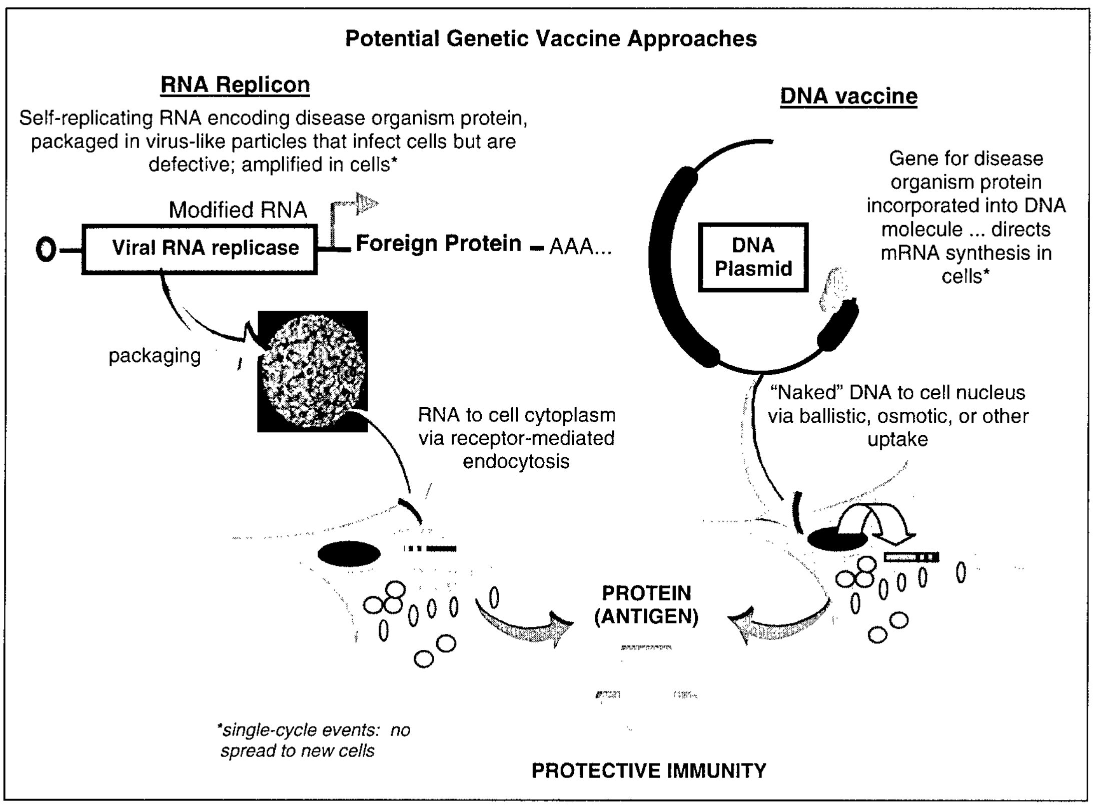
System/System Upgrade	Advanced Concept
Infectious Disease Pharmaceuticals	Tropical Warfighter Protection
Infectious Disease Vaccines	Desert Warfighter Protection
Infectious Disease Applied Medical Systems	Urban Warfighter Protection
Chemical Warfare/Biological Warfare Casualty Management	Mobilization Force Protection
Chemical Warfare Pretreatments & Treatments	Chemical Warfare/Biological Warfare Casualty Management System
Biological Warfare Countermeasures	Full-Spectrum Chemical Protection
Neurobiology & Performance Optimization	Multiagent Protective System
Environmental Medicine & Bioenergetics	Soldier Survival in Operational Environments Without Performance Decrements
Injury Prevention	Real-Time Soldier Effectiveness Models
Hemorrhage/Trauma Intervention	Biomedical & Performance Damage Risk Criteria
Life Support/Surgical Systems	Advanced Resuscitation
	Immediate Intervention & Continuum of Care

2 System Demonstrations

The Army Biomedical advanced technology development program is divided into four technology subareas: Infectious Diseases of Military Importance, Medical Chemical and Biological Defense (MCBD), Military Operational Medicine, and Combat Casualty Care. Each subarea focuses on a specific category of threat to the health and performance of soldiers. The first three subareas emphasize the prevention of battle and nonbattle injury and disease while the combat casualty care research program emphasizes far-forward treatment. All three prevention research programs provide both medical materiel (e.g., vaccines, drugs, applied medical systems) and biomedical information. Combat casualty care provides medical and surgical capabilities tailored to military medical needs for resuscitation, stabilization, evacuation, and treatment of all battle and nonbattle casualties.

a *Infectious Diseases of Military Importance*

The infectious diseases of military importance subarea supports systems of vaccines, pharmaceuticals, and applied medical systems (diagnostic devices, vector control, and threat assessment systems), all targeted at protecting soldiers against infectious diseases that are endemic in areas of deployment. Many of the demonstrations described below incorporate advanced molecular biological approaches to vaccine development (Figure III–22). Innovative diagnostic and vaccine technology development also supports and is supported by efforts in the MCBD area. So-called "molecular biologic" approaches to medical diagnostics, vaccines, and therapeutics take advan-



Genetically engineered DNA or RNA injected into the body induces human cells to produce disease organism proteins, which elicits an immune response that protects against later infection.

FIGURE III–22. GENETIC VACCINE APPROACHES

tage of newly gained knowledge of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA and RNA are the two chemical molecular forms used by all life to store and replicate coded genetic information necessary for replication and cell life functions. Scientists can use small segments of the DNA or RNA code of an infectious organism to represent the target organism to a vaccine recipient.

DRUG FOR PREVENTION OF RESISTANT MALARIA TD (2001–06). This R&D effort will seek to discover and conduct preclinical evaluation of a new drug to prevent malaria. This drug will replace currently available drugs that will become ineffective for prevention of malaria due to continuously evolving drug resistance of the malaria parasite.

DRUG TO TREAT MULTIDRUG-RESISTANT AND SEVERE AND COMPLICATED MALARIA STO (2001–03). This STO will demonstrate (in animal studies) a new intravenous drug formulation for the treatment of resistant and severe and complicated malaria. This product is a replacement for the currently fielded drug for this indication, for which future availability is doubtful due to manufacturer considerations. Efficacy and safety sufficient to obtain FDA approval for human studies and warrant transition of the candidate drug to advanced development will be demonstrated.

ADVANCED ANTIMALARIAL DRUGS TD (2001–09). This planned effort will expand capabilities demonstrated in the Drug Treatment for Severe Malaria TD (see above) by demonstrating effectiveness and safety of novel drugs to protect against or treat emerging forms of drug-resistant falciparum and vivax malarias.

A MULTISTAGE, MULTIANTIGEN PLASMODIUM FALCIPARUM MALARIA VACCINE STO (2000–04). This STO will demonstrate a first-generation vaccine candidate for protection against malaria caused by the parasite *Plasmodium falciparum*, one of the two major causal agents for human malaria. Several vaccine candidates will be produced and evaluated for efficacy and safety in limited human studies (i.e., FDA Phase 1/2a clinical trials), including peptide-based vaccines, recombinant protein-based vaccines, and nucleic acid vaccines containing different combinations of genes. Candidates resulting from this demonstration may be used alone or in combined immunization strategies in conjunction with other candidate malaria vaccines, with the goal of achieving at least 80 percent protection.

A MULTIANTIGEN, MULTISTAGE PLASMODIUM VIVAX MALARIA VACCINE STO (2001–07). A multivalent vaccine candidate will be developed for prevention of malaria caused by the parasite *Plasmodium vivax*. The vaccine candidate will induce immune protection by incorporating multiple parasitic proteins or genes to target the parasite at various stages in its life cycle. Safety and efficacy of the candidate will be demonstrated in limited human studies, and the product will be transitioned to development.

COMBINED MALARIA VACCINE TD (2005–10). The feasibility of a combined falciparum and vivax malaria vaccine will be assessed, incorporating novel (noninjection) delivery technologies and new protective determinants. The goal is a 10 percent increase in the protection afforded by single-agent-directed vaccines. This vaccine will reduce the logistical burden and simplify medical delivery.

PREVENTION OF DIARRHEAL DISEASES STO (2001–05). Individual candidate vaccines against each of the three principal causal *Shigella* species of dysentery, against *Campylobacter*, and against *Escherichia coli* (ETEC) will be demonstrated. Traditional vaccine technology using live attenuated (weakened) forms of the *Shigella* pathogen and a new technology, the proteosome/lipopolysaccharide

vaccine system, will be demonstrated. Against *Campylobacter*, the program will assess an improved vaccine based on recombinant protein(s). Against ETEC, the program has identified proteins on the bacteria that elicit strong protective immune responses. Recombinant DNA technology is being used to produce these components and combine them with a new form of adjuvant (a nonspecific immune system stimulant) incorporated into biodegradable microspheres.

ORAL MULTIDISEASE, ANTIDIARRHEAL VACCINE TD (2003–12). The feasibility of producing a more effective combined oral vaccine to protect against *Shigella*, *Campylobacter*, and ETEC will be assessed. This program will demonstrate advanced vaccine technology, such as recombinant, naked, or vectored DNA technology, and advanced adjuvants that stimulate immunity within the lining of the gastrointestinal tract. This vaccine will be easily administered, thereby reducing medical and logistical support requirements.

NUCLEIC ACID (DNA-BASED) VACCINES TO PREVENT DENGUE STO (2000–04). Dengue fever is a viral disease of major operational significance that is endemic in Central America, parts of South America and Africa, and Southeast Asia. A vaccine for dengue virus will be developed that will provide at least 80 percent protection of primates against a challenge with all four forms (serotypes) of the virus.

HANTAVIRUS VACCINES TD (2001–04). Four distinct hantaviruses are known to cause hemorrhagic fever with renal syndrome (HFRS). The efficacy of a recombinant multivalent hantavirus vaccine in reducing the threat of infection with viruses causing HFRS will be demonstrated. Two potential genetic vaccine approaches are being studied: a naked DNA/gene gun vaccine and an alphavirus replicon vaccine.

MENINGOCOCCAL VACCINE TD (2001–06). Bacterial meningitis can affect mobilization readiness, especially during basic training. A polyvalent vaccine for Groups A, C, W, and Y meningococcal bacteria is available. There is currently no protection against meningococcal Group B. Monovalent and multivalent Group B meningococcal vaccines will be demonstrated. The best Group B vaccine will ultimately be combined with the available polyvalent vaccine to reduce or eliminate all meningococcal infections in personnel during training.

HUMAN IMMUNODEFICIENCY VIRUS (HIV–1) VACCINE TD (2001–04). HIV–1 is a threat to force sustainment. The infectious disease program will demonstrate a candidate vaccine(s) capable of protecting against multiple subtypes of HIV–1 found worldwide. Products to be transitioned to development will consist of either multiple univalent vaccine constructs, each effective against a single HIV–1 subtype, or a multivalent construct capable of protecting against the most prevalent subtypes of HIV that have been identified in eastern Africa and southeast Asia.

COMMON DIAGNOSTIC SYSTEMS FOR BIOLOGICAL THREATS AND ENDEMIC INFECTIOUS DISEASES STO (2001–02). This demonstration is shared with the MCBD functional subarea. A field-portable (briefcase-sized) diagnostic platform will be demonstrated that detects the DNA of pathogens in biological samples. Developing a common diagnostic platform will ultimately reduce development time and expenses associated with individual assays, decrease logistical and training burdens, and provide early warning to limit the spread of infectious diseases and properly direct medical care for those who are infected. Systems should, at a minimum, be able to identify evidence of infection by militarily important pathogens in respiratory secretions (influenza, adenovirus), stool (*Shigella*, *Campylobacter*, ETEC, salmonella, Norwalk virus), blood (dengue, Lassa, malaria, meningococcus), urine, and cerebrospinal fluid (Japanese encephalitis, tick-borne encephalitis).

ADVANCED DIAGNOSTICS TD (2003–15). This planned demonstration will expand on the capabilities of the common diagnostic platform (see above) to reduce the size of the system to a portable unit, and incorporate detection of not only nucleic acids of the disease organism but also antibodies produced by the host in response to an infection. Diagnostic capability will be syndromic-based, addressing the most common syndromes faced by forward healthcare providers. This capability will greatly improve the sensitivity of detection and extend the time period during which accurate field diagnosis can be achieved.

DEVELOPMENT OF A NEW STANDARD MILITARY INSECT REPELLENT STO (2001–04). Problems with compliance and potential toxicity of the current military insect repellent have resulted in a requirement for a replacement product. This effort will select and demonstrate, through both laboratory and field testing, a new repellent formulation that is effective against insect vectors for a broad range of diseases, is safe, maximizes user acceptability, and resists loss from abrasion and wetting. Availability of a new repellent will provide tactical flexibility in that repellents can be applied to prevent any arthropod-borne disease. Such a repellent may be the only means of protection available in combat environments when no vaccines or drugs exist and other vector control measures are not possible.

INSECT VECTOR CONTROLS TD (2002–06). Effective control of disease-carrying insect vectors is hampered by inadequate understanding of insect threats, leading to indiscriminate application of pesticides that do not necessarily reduce targeted insect populations and can also have adverse environmental impacts. This effort will improve the effectiveness of disease prevention by demonstrating one or more integrated sets of materiel and information tools (e.g., insecticides, insect traps, expert systems for vector identification and threat assessment) each of which is tailored to address a specific operationally significant disease.

In addition to the major technology demonstrations described above, sustaining program efforts address vaccine and drug technologies for protection against several viral diseases, including tick-borne encephalitis; Lassa fever, Crimean–Congo hemorrhagic fever, and other viral hemorrhagic fevers; and hepatitis.

b *Medical Chemical and Biological Defense*

Systems supported within this functional area are medical chemical warfare agent (CWA)/biological warfare agent (BWA) casualty management, CWA pretreatments and treatments, and BWA countermeasures. Efforts focus on the demonstration of medical products for prevention, diagnosis, and treatment of diseases/injury caused by CWA/BWA threats and generation of medical knowledge for battlefield management of CB casualties. Diagnostic and vaccine technology developments in this area also support and are supported by efforts in the Infectious Diseases of Military Importance area. The Gulf War illnesses research program managed by the Military Operational Medicine Research Program also generates information directly relevant to studies of the effects resulting from exposure to low levels of CWA. The following descriptions illustrate current technology demonstrations.

COMMON DIAGNOSTIC SYSTEMS FOR BIOLOGICAL THREATS AND ENDEMIC INFECTIOUS DISEASES STO (1998–03). This demonstration is shared with the Infectious Diseases of Military Importance functional area (see description on page III–69). The purpose of this demonstration is to develop diagnostic assays and reagents that will provide rapid laboratory diagnosis for a broad array of biological threats and infectious diseases using common diagnostic technologies.

ACTIVE TOPICAL SKIN PROTECTANT (ATSP) TD (1995–02). The ATSP is a reactive moiety in the skill exposure reduction paste against chemical warfare agent (SERPACWA), which upon application to skin will prevent skin contact with all CW agents and will detoxify both vesicant and nerve agents. Efforts will explore the use of enzymes and other catalytic molecules and resorptive resins. The ATSP will enable the soldier to fight in a CW battlefield with greater protection. Proof of concept occurred in FY00.

CHEMICAL AGENT PROPHYLAXIS STAGE II TD (1994–02). The feasibility of a reactive or catalytic scavenger pretreatment that reduces or eliminates chemical agent toxicity without significant physiological or psychological side effects was demonstrated (Stage I). Current treatment for nerve agent intoxication must be administered very soon after exposure, and the warfighter will still likely be incapacitated. Development of an effective catalytic scavenger that would detoxify the nerve agent before it affects the warfighter would alleviate some of the commander's battlespace concerns, be psychologically beneficial to the warfighter, and eliminate reliance on a multidrug approach to treat nerve agent exposure. Current efforts focus on the molecular engineering of enzymes (e.g., butyrylcholinesterase, an enzyme found in blood) that normally bind to nerve agents. Proof of concept was demonstrated in FY00.

MEDICAL COUNTERMEASURES AGAINST VESICANTS STAGE II TD (2001–03). This effort will conduct advanced evaluations of safety and efficacy of promising candidate drugs to downselect the best candidates for treatment of blisters resulting from vesicant exposure. Single and multiple drug approaches will be considered, and the candidate(s) demonstrating greatest safety and efficacy will be transitioned to Phase I.

MEDICAL COUNTERMEASURES FOR *YERSINIA PESTIS* TD (1994–01). Efficacy and safety will be demonstrated for a novel vaccine based on a fusion protein, produced through molecular recombination and expression of the genes for two different proteins of the pathogen. This vaccine will protect 80 percent of immunized personnel against an aerosol challenge of *Yersinia pestis.*

MEDICAL COUNTERMEASURES FOR BRUCELLOSIS TD (1994–03). This demonstration will evaluate candidate vaccine technologies for a genetically engineered, well-characterized, live-attenuated cell vaccine. By FY03, a vaccine capable of protecting 80 percent of immunized personnel against an aerosol challenge of *Brucella* will transition to advanced development.

MEDICAL COUNTERMEASURES FOR ENCEPHALITIS VIRUSES TD (1996–03). Efficacy and safety will be demonstrated for vaccines directed against various members of the equine encephalitis viruses, a group of viruses that cause disorientation, convulsions, paralysis, and death. Site-directed mutagenesis—a molecular biological technique that induces specifically designed mutations in essential genes of the pathogen—will be used to produce replicons that elicit a protective immune response without causing disease. Vaccines will protect 80 percent of the immunized population against an aerosol exposure with minimum reactogenicity. By FY03, a multivalent equine encephalitis, Venezuelan equine encephalitis, Eastern equine encephalitis, and Western equine encephalitis vaccine should transition to advanced development.

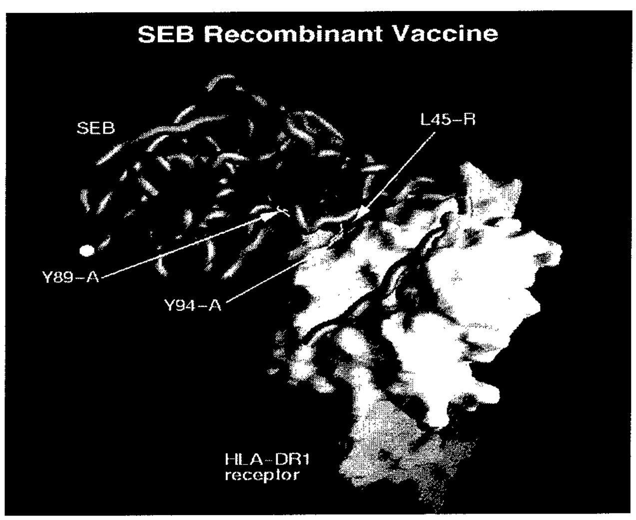
MEDICAL COUNTERMEASURES FOR FILOVIRIDAE STO (1996–06). Safe and effective medical countermeasures against filoviruses, including Marburg and Ebola viruses, will be demonstrated. Naked DNA vaccine and replicon technologies are offering promise for protection against these and other BW threat agents. Naked DNA technology uses DNA fragments from pathogens of interest, which are then injected into skin cells. The cells' protein production machinery produces proteins from the pathogen DNA, which then elicits an immune response that can later protect

against the live pathogen. An alternate strategy is to use a replicon system. The latter is a vectored system in which portions of the pathogen genes are combined with a portion of viral DNA that allows the bioengineered DNA to be introduced into cells by the normal viral mechanisms and replicated a single time, after which it is eliminated. An effective vaccine against Marburg virus will be transitioned to advanced development by FY03; a candidate vaccine against Ebola virus is expected to transition to advanced development in FY06. This STO also evaluates immunotherapeutic approaches for post-exposure treatment and short-term protection.

MEDICAL COUNTERMEASURES FOR ORTHOPOX VIRUSES STO (1997–01). This demonstration will assess the use of human monoclonal antibodies to replace vaccinia-immune globulin in providing passive (short term) immunity to variola, the causative agent of smallpox. Antiviral drugs for post-exposure treatment will also be screened to identify effective countermeasures. These studies will not use variola itself, but will instead employ an appropriate orthopox virus substitute. Screening and identification of effective antiviral drugs for post-exposure treatment should be completed by FY01.

MEDICAL COUNTERMEASURES FOR RICIN TD (1996–05). By FY05, this effort will demonstrate efficacy and safety of a recombinant vaccine against ricin. The vaccine candidate will protect 80 percent of the immunized population against an aerosol challenge in animal models and will induce minimum reactogenicity in soldiers when immunized.

MEDICAL COUNTERMEASURES FOR STAPHYLOCOCCAL ENTEROTOXINS TD (1996–02). A bioengineered vaccine will be demonstrated that protects 80 percent of immunized animals against a lethal or incapacitating aerosol challenge. This recombinant product (Figure III–23) will offer potential safety and affordability advantages over the originally proposed toxoid candidate. It is expected that by FY02 transition of the vaccine candidate to advanced development will be underway.



Modeling of SEB interaction with its primary receptor led to identification of site-specific mutations in the SEB protein that enabled it to serve as a vaccine while minimizing its toxicity.

FIGURE III–23. PROTEIN STRUCTURAL MODELING FOR DEVELOPMENT OF A STAPHYLOCOCCAL ENTEROTOXIN B (SEB) VACCINE

MULTIAGENT VACCINES FOR BIOLOGICAL THREAT AGENTS STO (1998–03). A vaccine delivery methodology will be demonstrated that concurrently provides protective immune response against at least three biological threat agents. Combination vaccines offer an approach to immunization that reduces the number of injections to one single preparation, minimizes required medical support, and lowers costs. Recombinant DNA vaccine technology offers the possibility of combining gene products from multiple agents into a single delivery vehicle. Candidate vaccine technologies to be assessed will include naked DNA technologies and a replicon system. By FY03, a multiagent vaccine delivery system will be demonstrated that protects 80 percent or more of immunized animals from death or incapacitation by at least three specific biological agents following aerosol exposure. Subsequent to a successful demonstration, efforts will be focused on bringing a specific medical product to advanced development.

In addition to the major technology demonstrations described above, the MCBD subarea executes basic and applied research designed to identify and develop concepts for next-generation pretreatments/prophylaxes and post-exposure therapeutics for validated CWA/BWA threats, improved vaccine and drug delivery systems, advanced integrated portable diagnostic platforms, and protection from and treatment of diseases from emerging BW and novel CW threats.

c *Military Operational Medicine*

Thrust areas supported within this subarea are neuropsychological stress and performance, environmental medicine and bioenergetics, and systems hazards. A primary objective of military operational medicine demonstrations is the transition of physiological data, models, and algorithms to materiel developers and policymakers to enhance medical readiness and sustainability during deployments. These include technical insertions to Land Warrior and follow-on systems for real-time command consultation; furnishing real-time intelligence on warfighter readiness, sustainability, and recovered capability; biomedical and performance damage risk criteria and models ensuring that soldier health and performance are not degraded by their own equipment; and identification of nutritional, pharmacological, and training strategies ("skin-in" interventions) to sustain performance in the face of operational stressors. The physiologically based models produced through efforts within this functional area provide a key basis for integration of the human dimension into higher level models and simulations of unit effectiveness.

PHARMACOLOGICAL STRATEGIES TO ENHANCE MENTAL PERFORMANCE IN FATIGUED SOLDIERS STO (2000–03). This STO will provide specific pharmacological interventions to sustain performance when adequate sleep is not possible and to optimize the recuperative value of sleep or adjustment to new time zones when the opportunity for sleep is presented or is impaired by environmental conditions. Candidate interventions with potential high payoff include certain stimulant drugs for performance sustainment, drugs for sleep induction, and melatonin for rapid adjustment of circadian rhythms to new time zones or work schedules. This STO will produce field medical guidance and FDA-approved indications for existing pharmacological products.

MILITARY HEALTH BEHAVIORS PROMOTION/INTERVENTIONS TD (1999–05). This TD will provide strategies that significantly improve medical readiness by reducing illness and injury during training and deployments associated with personal health habits, including smoking, alcohol abuse, weight management, physical activity, and unintended pregnancy. Guidelines will be developed to increase soldier fitness and promote health behaviors that reduce illness and lost duty time.

OPTIMIZATION OF PHYSICAL PERFORMANCE STO (1999–03). This STO will address noncombat injuries, the leading risk to deployment health and readiness. It will lead to the optimization of training

programs to reduce injury from physically mismatched individuals to military tasks and equipment and maximize physical readiness through nonmaterial (skin-in) solutions. This STO is coordinated with another TD on biomechanics of load carriage that will develop biomechanical methods, design guidance, physical training regimens, and predictive analytical and statistical methods addressing the human locomotion and load-bearing functions of the warfighter system to enhance the efficiency of overground movements and the fitness of dismounted troops to fight.

OPTIMIZATION OF PHYSICAL PERFORMANCE WITH OPTICAL AND ELECTRO-OPTICAL SYSTEMS AND MATERIALS STO (2000–04). This STO will provide the Army with essential bioengineering data and evaluations of the impact of displays on visual performance. These can be used to guide the optimal design of advanced imaging and display technologies to solve battlefield problems, such as degraded fighting environments and directed-energy, chemical, and biological weapons. It will produce improved image output standards to optimize visual performance with advanced electro-optical designs and visual performance models to predict soldier performance in an operational environment.

DEPLOYMENT STRESS MODELS AND COUNTERMEASURES TD (1997–03). This TD will lead to quantitative models that accurately predict the impact of operational and personnel tempo on soldier and unit readiness. Preventive measures will be developed to avoid stress casualties and sustain performance across the span of operational deployments, from contingency operations to intense combat. Methods for early detection and immediate intervention will be developed to identify sources of stress and reduce stress casualties by at least half of current projections.

PERFORMANCE ENHANCEMENT AND INJURY PREVENTION IN HOT ENVIRONMENTS STO (2000–04). This STO will provide methods to sustain and enhance soldier performance in hot environments to ensure readiness to respond to the full spectrum of operations with agility and versatility. It will establish the scientific foundation and methods to manage and minimize the adverse health and performance effects of heat stress, especially as encountered in desert and jungle environments.

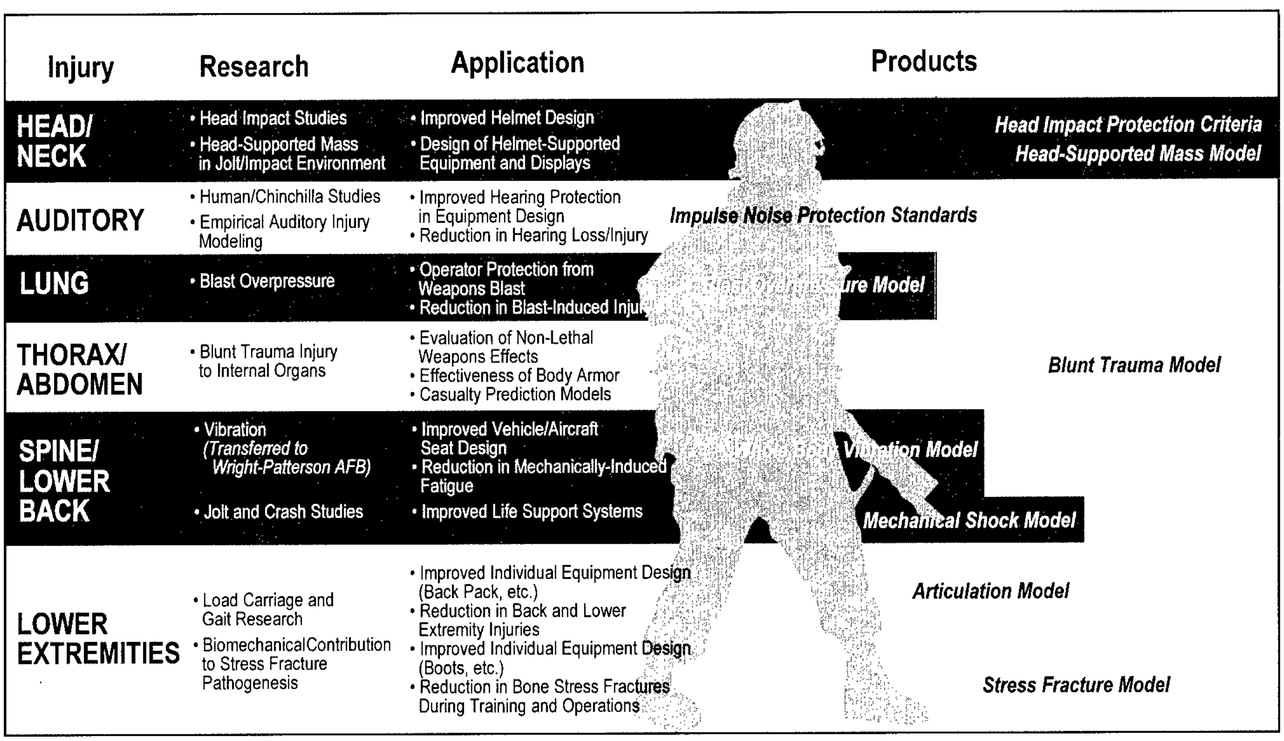
FUSION OF WARFIGHTER PERFORMANCE, ENVIRONMENTAL, AND PHYSIOLOGIC MODELS STO (1997–03). This demonstration will provide commanders with rapid access to basic information on the physiological readiness of their warfighters. A family of physiological sensors will be developed to gather data on warfighter status. Data will be organized and reduced through knowledge management tools. This STO assembles the relevant knowledge of physiological and cognitive processes under extreme conditions and provides algorithms and models to interpret the status of the force for the commander. It will transition models and decision aids, such as the warfighter physiological status monitoring; operational planning tool for unit performance and logistical support (Integrated Unit Simulation System, Janus); and integration with environmental/weather sensor system for real-time risk assessments of operations (Mercury). All systems will be compatible with Land Warrior and follow-on programs.

INNOVATIVE STRATEGIES TO ASSESS HEALTH RISKS FROM ENVIRONMENTAL EXPOSURE TO TOXIC CHEMICALS STO (2000–04). This STO will address the potential health hazards to soldiers exposed to toxic industrial/agricultural chemicals (TICs) and military relevant chemicals (MRCs), not including CW threat agents. Recent deployments, the development of sophisticated weapon systems, and the involvement of women in all aspects of deployments have heightened concerns about the risks of these chemicals. This STO will provide (1) low-cost screening tools to assess health risks (e.g., reproduction, birth defects, immune suppression) from environmental exposures to TICs, MRCs, and chemical mixtures; and (2) instrumented animal models (sentinel species) to aid in

assessing health risks from environmental exposures to chemicals during training and deployments and to chemical contaminants from past industrial operations on military installations. It will provide methods to evaluate the safety of water and food to protect deployed forces from incidental or purposeful contamination of these vital commodities. This STO will develop physiologically-based predictive models of injury, incapacitation, and degraded performance relevant to military scenarios involving inhaled toxic substances (e.g., MOUT on smoke-filled buildings, armored vehicles penetrated by offensive rounds, fires in enclosed spaces).

LASER BIOEFFECTS AND TREATMENT STO (1997–02). This STO will provide medical countermeasures to protect warfighter vision from directed-energy lasers. Through a thorough understanding of the relative risks of different forms of laser energy, it will provide medical exposure standards to guide system developers for the avoidance of the most harmful frequency and power mixes. Basic bioeffects research will lead to effective field treatment interventions for laser eye injuries.

WHOLE BODY BLAST BIOEFFECTS/BLUNT TRAUMA INJURY MODELS TD (1999–04). This TD will develop scientifically valid predictive models of blunt trauma injury effects for applications such as health hazard assessments of military materiel, assessment of nonlethal weapon effects, body armor evaluations, and casualty prediction models. This TD contributes to development of an integrated total body injury and performance model. The products of this TD emphasize injury to surface and internal organs of the thorax, abdomen, and head. These models will be merged with separate efforts to develop models of neck and spinal injury and articulated extremity injury models to produce an integrated biomechanical injury model (Figure III–24).



Current research in biomechanics will produce specific models for performance degradation and injury risks that begin to build an integrated biomechanical injury model.

FIGURE III–24. BIOMECHANICS RESEARCH

INJURY PREVENTION AND RESTRAINT TECHNOLOGIES FOR GROUND VEHICLES AND HELICOPTERS STO (2000–04). This STO will provide for the first time occupant restraint systems for ground vehicles and will enhance restraints for helicopters by leveraging state-of-the-art knowledge and engineering designs from the commercial automotive industry. Potential restraint systems include the Cockpit Airbag System (CABS). This STO will address performance and safety concerns regarding CABS design related to the helicopter crash pulse and unintended airbag deployment. In addition, health hazards assessment will be conducted related to ride quality (e.g., repeated jolt) leading to health hazards standards. It will provide generic assessment methodologies, injury probability models, integrated design parameters for restraint system configuration and performance, and data for a national standard for repeated jolts.

HEAD-SUPPORTED MASS: WARFIGHTER HEALTH AND PERFORMANCE STO (2001–05). This STO will provide operational guidelines, design criteria, and health risk criteria for mass properties of head-supported devices. Head-supported devices with misplaced centers of mass or large weight can degrade warfighter performance and increase the risk for chronic and acute injuries. The biomedically-based guidelines and criteria from this STO will enhance the effectiveness of head-supported devices while reducing the risk of injuries associated with their use. It contributes to development of an integrated total body injury and performance model.

d *Combat Casualty Care*

Systems supported within this functional area are hemorrhage and trauma interventions and life-support and surgical systems. Hemorrhage and trauma interventions are a family of products intended for use immediately after injury to enhance resuscitation through effective prevention or limiting of hemorrhage, and modulation of the secondary organ damage that results from hemorrhage or other major trauma. Life-support and surgical systems are a family of medical devices, software, and associated medical knowledge that will enable the projection of advanced life support and surgical care with the force, and will enable maintenance of critical care through evacuation to CONUS (Figure III–25).

BLOOD PRODUCTS STO (2001–05). This demonstration will support the development of techniques or technologies to improve the acquisition and availability of blood products and reduce the medical and logistic requirements for the care of casualties with hemorrhagic shock. These efforts will identify technologies for sterilization of blood from blood-borne pathogens, develop a blood-borne pathogen testing kit, complete clinical trials of a 10-week red blood cell storage solution, and complete development of freeze-dried plasma.

OPTIMAL PARAMETERS FOR THE BATTLEFIELD RESUSCITATION OF COMBAT CASUALTIES STO (2001–08). This demonstration will develop an optimal resuscitation strategy for combat casualties suffering from hypovolemia due to hemorrhage, giving special emphasis to strategies designed to improve survival when evacuation is delayed and resources are limited. These efforts will identify potential novel markers indicating the need for resuscitation, and select an optimal resuscitation fluid based on comparison of different prospective resuscitation fluids.

HEMORRHAGE CONTROL STO (2001–07). This STO will provide a suite of products and methods that will reduce the number of deaths due to hemorrhage in battlefield casualties. It will also define how long a tourniquet may be left in place without causing irreversible tissue damage. Other efforts will develop new or improved hemostatic devices and biologic agents for use on compressible hemorrhage under far-forward field conditions. This demonstration will identify or develop drugs or biologics that enhance the clotting function during hemorrhage. A hemostatic

- **Advanced hemostatic agents for control of internal bleeding**
- **Optimized resuscitation fluid**
- **Neuroprotective drugs for trauma**
- **Blood and blood products with enhanced storage characteristics**
- **Field medical monitoring and therapeutic devices**
- **Surgical products for hard and soft tissue repair**
- **Field dental systems and preventive measures**
- **Medical modeling and simulations**

Far-Forward Interventions will save lives!

Combat casualty care focuses on enhancing the capability to effectively treat casualties as close to the geographic location and time of injury as possible. (Center: advanced warrior medic; clockwise from top left: fibrin bandage, dried plasma, high-velocity gunshot wound, miniature IV pump, laser welded vein, handheld dental x-ray, mini STAT, virtual reality medical trainer, one-handed tourniquet, and new resuscitation fluid).

FIGURE III–25. COMBAT CASUALTY CARE

agent (i.e., a foam, gel, or other formulation) will be developed that may be used under far-forward field conditions for controlling hemorrhage that is not compressible, such as intra-abdominal and intrathoracic hemorrhage. Finally, it develops or identifies drugs or other compounds that act systemically for the control of hemorrhage under far-forward field conditions.

FIELD MEDICAL MONITORING AND THERAPEUTIC DEVICES FOR CASUALTY CARE STO (2001–08). This effort will demonstrate the first generation of advanced, noninvasive physiologic sensors and diagnostic algorithms for detection of a penetrating or blunt trauma wounding event and for remote triage. The sensors will target physiological variables for continuous, noninvasive monitoring that may include heart rate, respiratory rate, blood pressure, hemoglobin saturation, cardiac output, a measure of central nervous system integrity, and a measure of base deficit. This TD will demonstrate full-sized and miniaturized critical care systems for casualty trauma treatment and transport, a digital medical imaging system, a ceramic-based oxygen generating system, and advanced triage and medic-assist algorithms. This STO will also provide lightweight, low-

power, easy-to-use equipment to diagnose and treat potentially preventable acute causes of death such as airway obstruction and tension pneumothorax.

NEUROPROTECTION TD (2000–12). This TD will develop a neuroprotective drug for penetrating head injury protection and improve technologies for managing head trauma. By providing the medic with biologics and pharmaceuticals to increase survival by reducing trauma sequelae, such neuroprotective treatment strategies will significantly improve the prognosis for functional recovery of the soldier following brain and spinal cord injuries.

DENTAL DISEASE REDUCTION TD (2000–07). This demonstration supports the development of dental systems with less cube, weight, and energy requirements for use in the war zone. This TD will also develop antiplaque and anticaries peptides for incorporation into meals ready to eat and a 30-minute cold sterilization solution.

ADVANCED TRAUMA PATIENT SIMULATION STO (2001–03). This STO will develop a common medical modeling and simulation (M&S) environment for initial, refresher, and sustainment training, providing a basis for further development of medical skills training systems. A prototype system will be developed and demonstrated that incorporates a medical simulator, improves core competency levels on tasks identified on the Medical DoD Task List of patient condition codes, and is interoperable with other medical simulation systems.

MEDICAL MODELING AND INFORMATICS TD (2000–10). This TD will develop a virtual reality-based simulator that incorporates haptic feedback capabilities for medic training.

JOINT MEDICAL OPERATIONS—TELEMEDICINE ACTD (1999–02). This ACTD will evaluate alternatives for delivery of healthcare support during joint operations in austere and nonlinear environments. Novel M&S tools will be evaluated that enable tailoring of medical systems to enhance deployability and interoperability. This demonstration will also evaluate the use of telecommunications and groupware utilities as medical planning tools and enablers of situational awareness. Finally, the utility of novel medical devices, telecommunications equipment and protocols, and enabling tactics, techniques, and procedures will be evaluated for their ability to enhance access of dispersed forces to medical care.

3 Roadmaps

Modernization roadmaps for the four biomedical subareas are shown in Figures III–26, III–27, III–28, and III–29. Figure III–30 illustrates significant products that are expected to transition out of biomedical S&T in the coming decade.

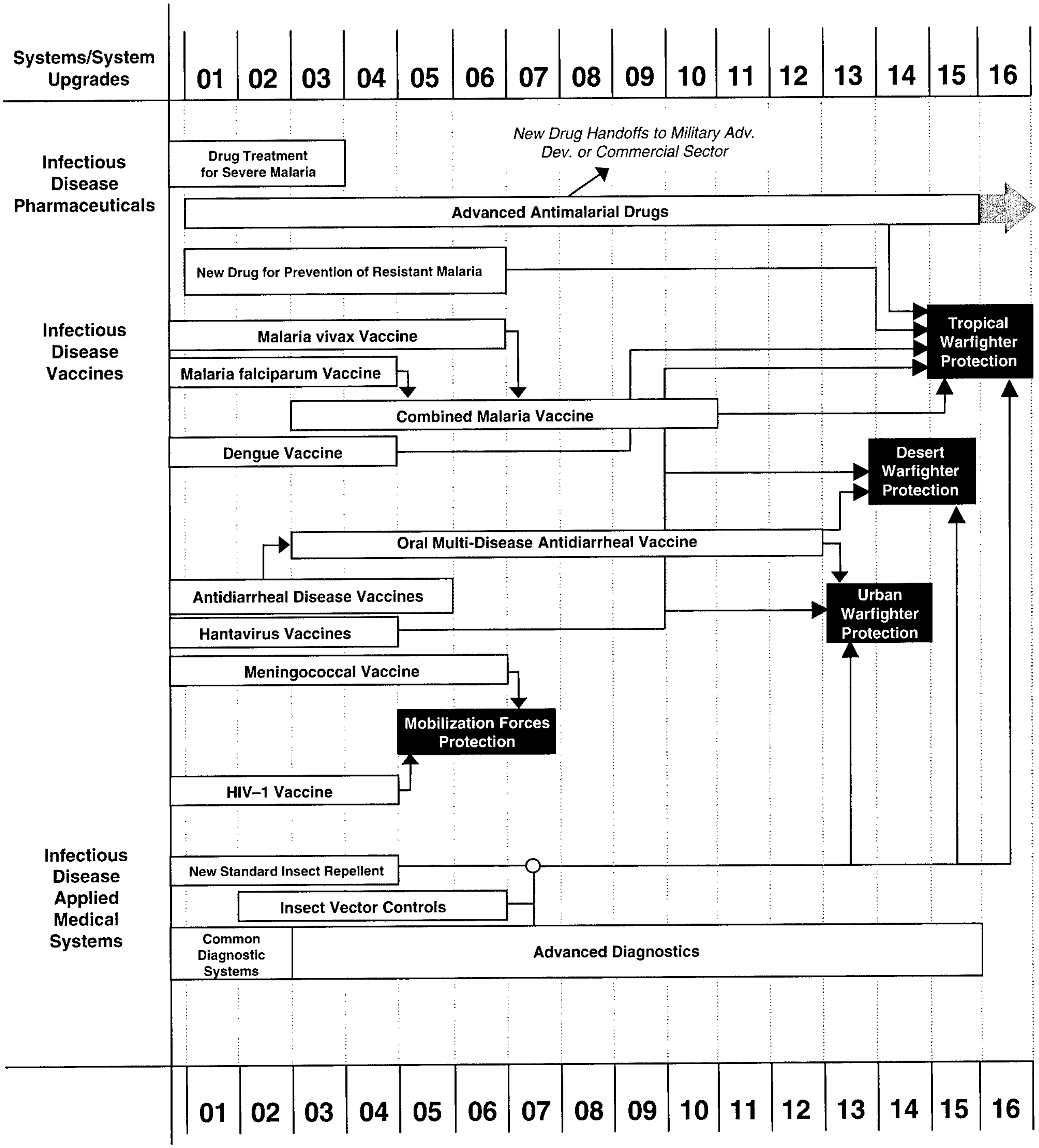


FIGURE III–26. ROADMAP—BIOMEDICAL: INFECTIOUS DISEASES OF MILITARY IMPORTANCE

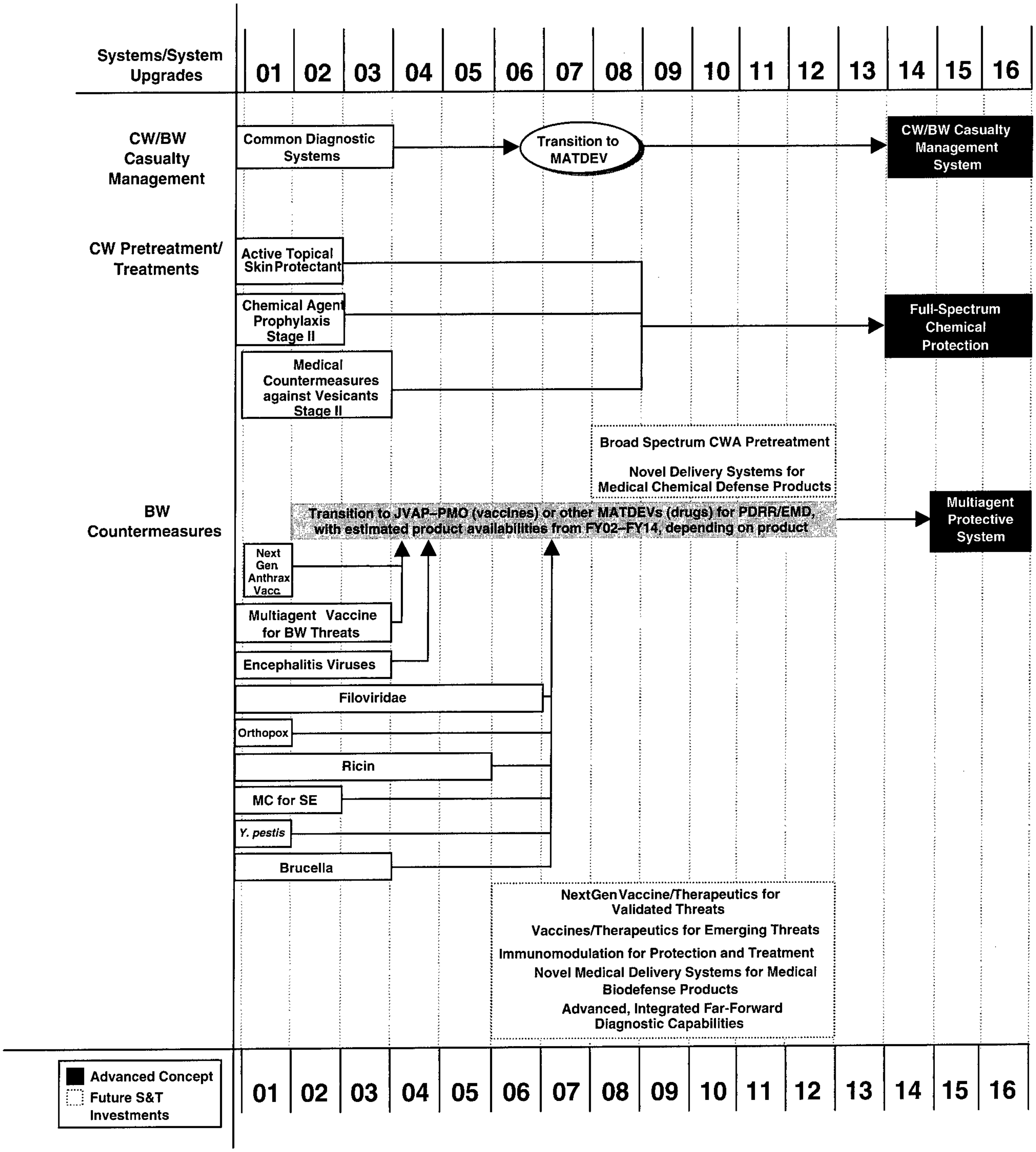


FIGURE III–27. ROADMAP—BIOMEDICAL: MEDICAL CHEMICAL AND BIOLOGICAL DEFENSE

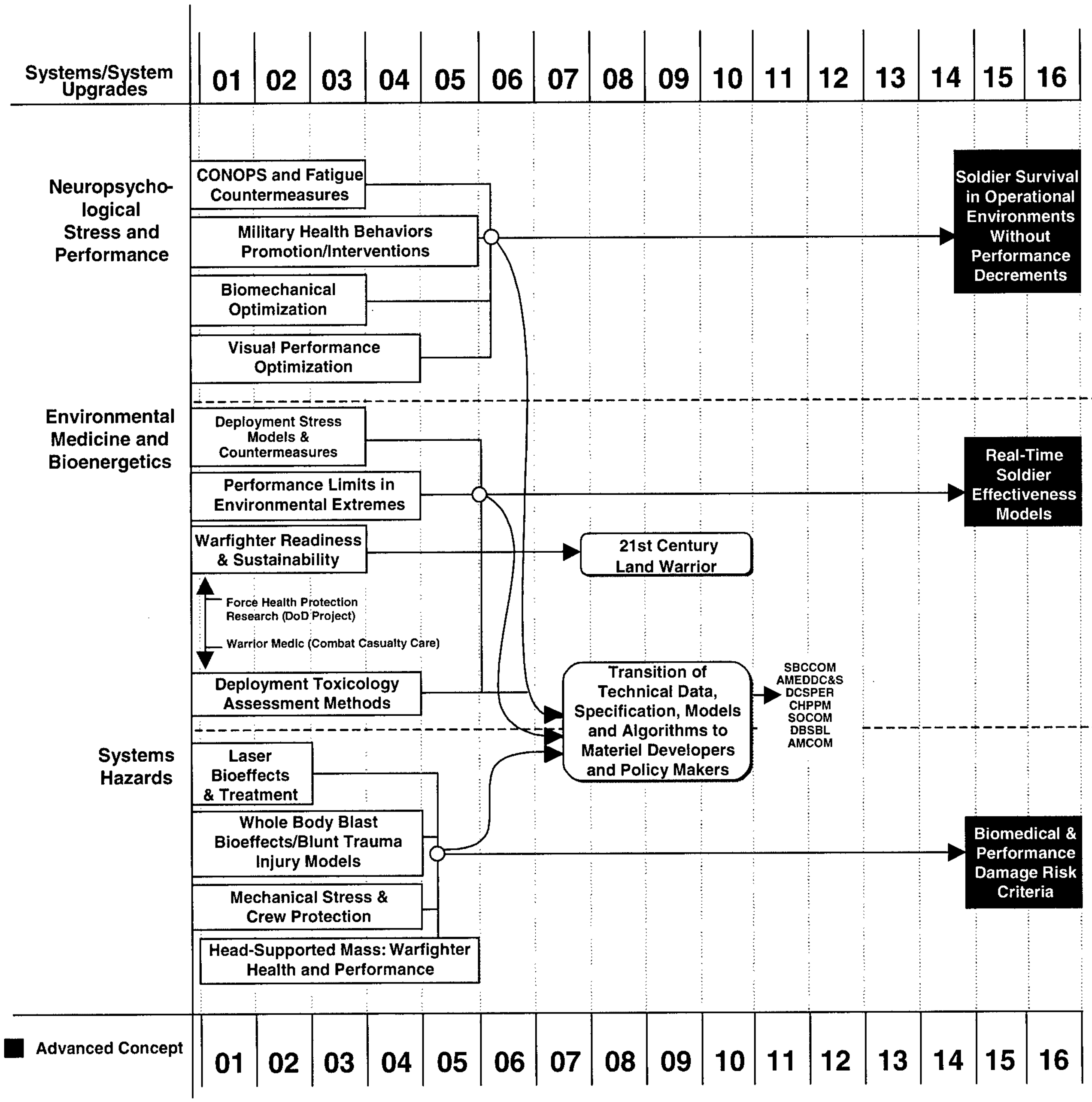


FIGURE III–28. ROADMAP—BIOMEDICAL: MILITARY OPERATIONAL MEDICINE

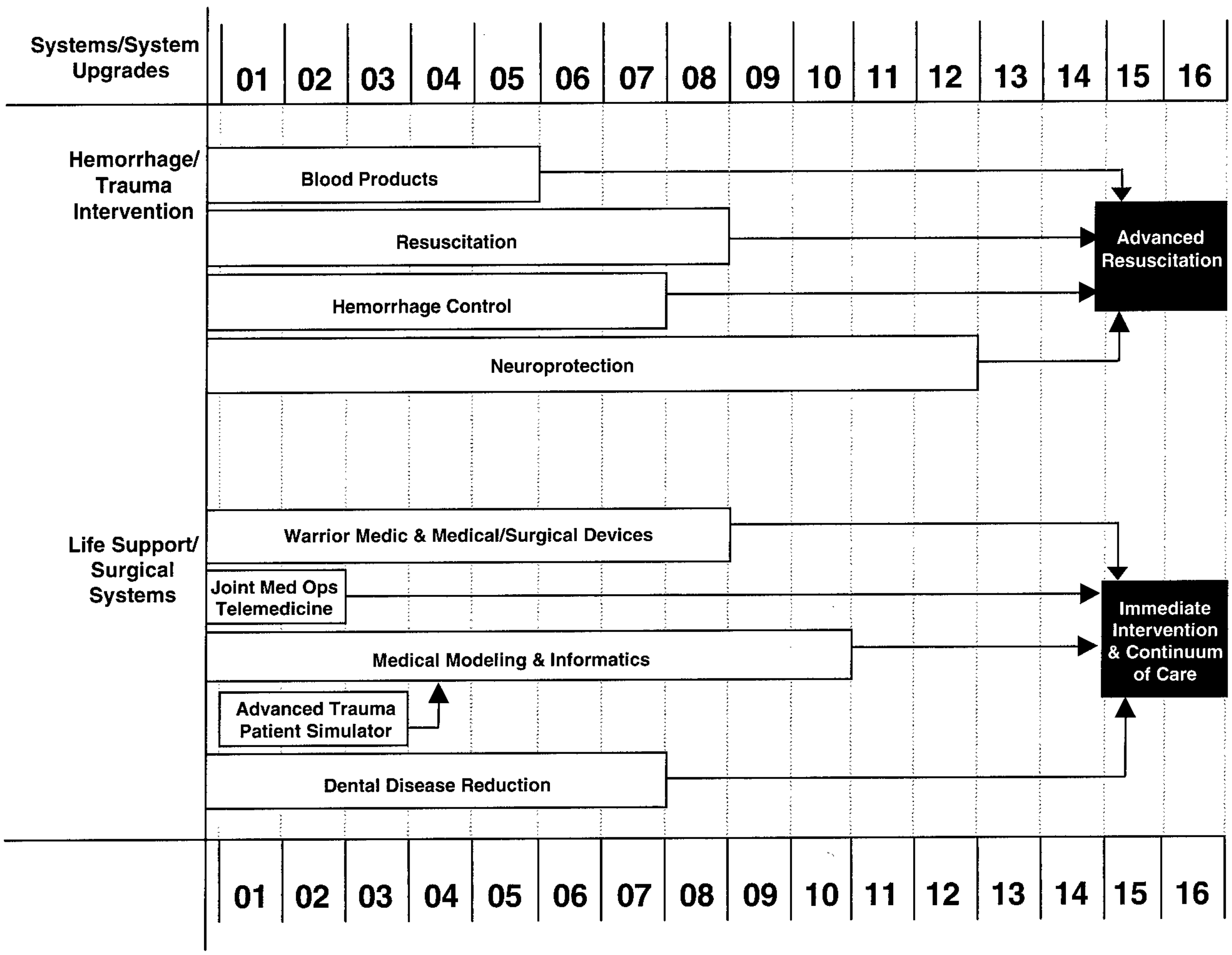


FIGURE III–29. ROADMAP—BIOMEDICAL: COMBAT CASUALTY CARE

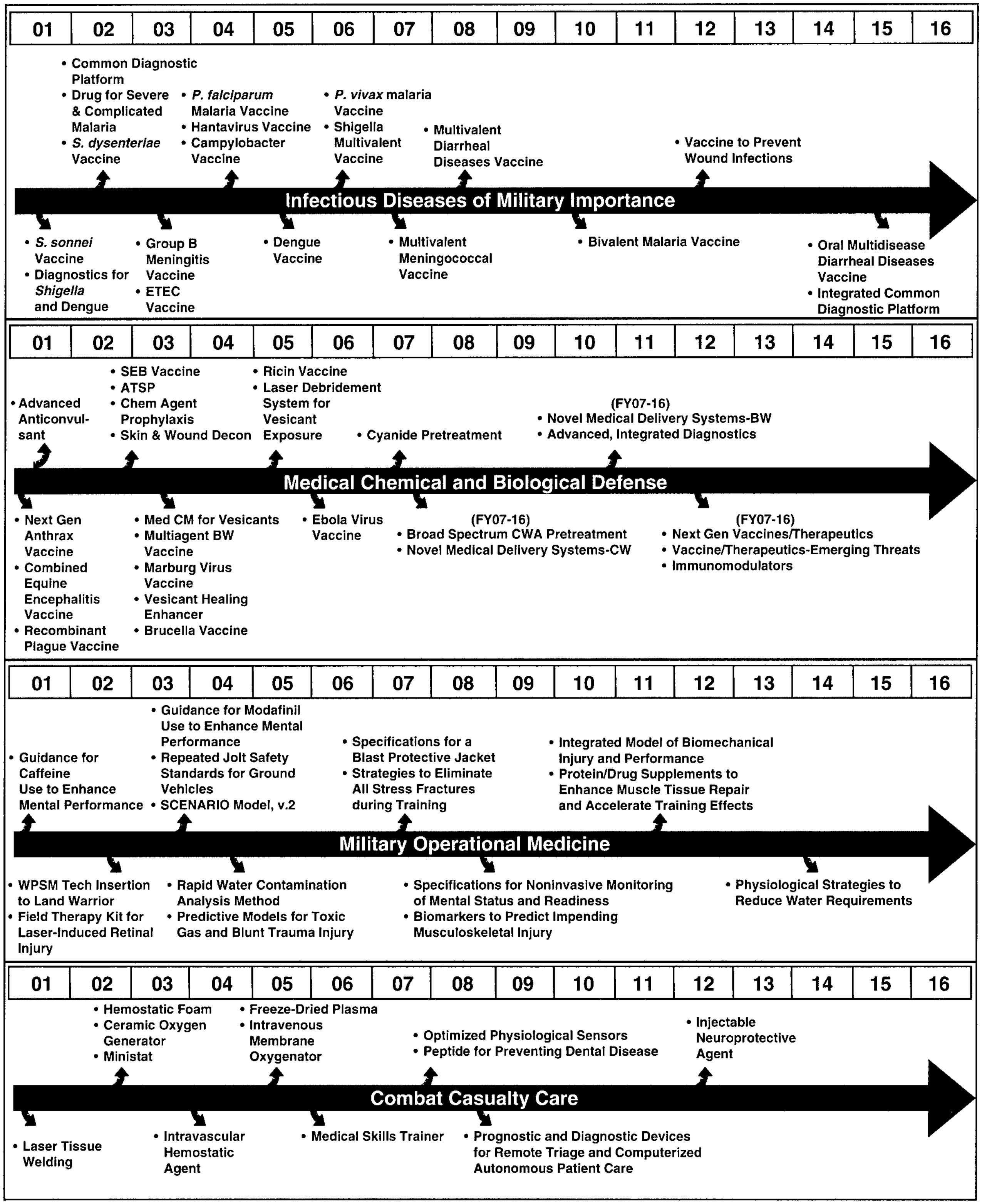


FIGURE III–30. ANTICIPATED PRODUCT TRANSITIONS FOR S&T

J CHEMICAL/BIOLOGICAL DEFENSE

Chemical and biological defense programs must be structured to counter a growing asymmetrical threat, including terrorism and continued weapons of mass destruction (WMD) proliferation in spite of the Chemical Weapons Convention and the Biological and Toxic Weapons Convention. Technology must cope with individual acts of terrorism using both established and newly developed chemical or biological agents as well as providing traditional CBD support to warfighters in the battlespace. The services' CBD program is jointly managed with leadership by the Defense Threat Reduction Agency (DTRA). Defense against chemical and biological agents and nuclear effects and contamination is conducted with and principally funded by DTRA. The other principal area of chemical technology—smoke, obscurants, and flame (weapons)—is managed by the Army.

Defense against CB agents is accomplished at several levels: enhancing survivability of combat forces, battle management, warning of units and personnel, detecting and identifying CB agents, protecting personnel after agents are employed, decontaminating following CB agent employment, and providing safe and effective medical support. Modernizing FCS for survivability includes CBD as well as the use of smokes and obscurants. NBC battle management enhances warfighter survivability by providing the critical link between detection and protection through quantification, digitization, visualization, and communication of the NBC threat in the battlespace. In support of FCS, the CBD technology program addresses:

- *Individual and Collective Protection*—Protect the joint force and allow it to operate safely, effectively, and efficiently while under NBC threat or in an NBC hazard area. Enhance filtration systems.
- *Contamination Avoidance*—Significantly improve operations in an NBC environment by rapidly detecting, locating, identifying, confirming, and disseminating NBC defense information to the joint force. Primary emphasis is on detectors and systems that provide early warning.
- *Decontamination*—Develop effective, environmentally low-impact CB decontamination systems to neutralize toxic materials without damaging the contaminated surface or affecting system performance.
- *Smoke and Obscurants*—The smoke and obscurants program is designed to improve survivability of FCS and the Objective Force through the use of millimeter-wave (MMW) screening, advanced IR obscurants, and distant smoke.

Any nation with the will can turn its legitimate medical, biotechnological, and chemical facilities to the development of a formidable offensive chemical and biological warfare (CBW) capability. With the necessary resources, a nation can develop an offensive nuclear warfare capability. The sale of technology and loss of control over WMD in various world regions can greatly accelerate the acquisition of WMD programs and weapons. Recent incidents underscore the potential for terrorist use of NBC materials. Proliferation increases the asymmetric threat of WMD being used against the United States and its allies during contingency operations.

Title XVII of the National Defense Authorization Act for FY1994 (P.L. 103–160) required DoD to consolidate management and oversight of the CBW defense program in a single office within the OSD and to execute oversight of the program through the Defense Acquisition Board. The public law designated the Army as the executive agent for coordination and integration of the program and consolidated NBC warfare defense training activities at the U.S. Army Chemical School. In that capacity, the Army presents the nonmedical CBD programs in this section, biotechnology programs in Section IV–P, "Biotechnology," and the medical CBD (MCBD) programs in Section III–I, "Biomedical." Funding for all NBC defense research, development, and acquisition (RDA) is now consolidated within OSD. Individual service requirements and programs are now consol-

idated in a truly joint integrated strategy. The FY02–07 Joint Service NBC Defense program objective memorandum increased NBC defense nonmedical S&T funding by over 50 percent (along with a substantial increase in medical S&T funding). Although this funding has not been allocated among the services, the Army can expect a substantial funding increase in this area.

The CB program reflects future joint service requirements and is consistent with the *Joint Service NBC Modernization Plan*, the NBC defense Joint Future Operational Capabilities, the *Joint Service NBC Defense RDA Plan*, and the *DoD CB Defense and Nuclear Technology Area Plan*. It contains modernization strategy, systems demonstrations, and roadmaps for the CBD functional areas.

1 Modernization Strategy

The CBD modernization strategy emphasizes technology demonstrations incorporated into the front end of critical development programs. The CB modernization strategy reflected in this section represents the emerging joint service defense strategy in contamination avoidance, protection (individual and collective), and decontamination, and the Army's strategy in smoke and obscurants. Smoke and obscurants provide a potent combat multiplier by increasing the effectiveness of certain weapon systems, countering enemy reconnaissance, surveillance, and target acquisition (RSTA) efforts, conserving effective combat power, and supporting deception operations.

Modernization efforts will be implemented through horizontal integration of CB capabilities into major weapon systems such as the current FCS force initiative. Acquisition of CB materiel will be conducted via technology insertions, product improvements, and advanced concepts. Integration efforts such as these will ensure significant gains in operational survivability and mission sustainment at modest incremental costs. The joint CB modernization strategy is postured to meet the challenges facing U.S. forces in the 21st century.

NBC DEFENSE STRATEGY GOALS

Provide rapid field biodetection and identification capability

Extend range and coverage of CB standoff and early warning detection capabilities

Integrate CB sensors and systems with the digitized battlefield

Maintain current protection capability while reducing degradation associated with individual protective equipment

Develop continuous, regenerable collective protection filtration systems integrated with environmental controls requiring minimal logistics and capable of addressing emerging future NBC threats

Develop effective, low-environmental impact decontamination systems that do not damage contaminated surfaces

Enhance CB M&S capabilities to allow concept technology and system evaluations, hazard assessment, and realistic training for the CB-contaminated battlefield

THRUST OF THE SMOKE AND OBSCURANT TECHNOLOGY STRATEGY

Enhance the capability of smoke/obscurants to defeat enemy RSTA capabilities by selectively dominating the EM spectrum, thus allowing the maneuver commander to control the maneuver space

Enhance the survivability of the individual soldiers and vehicles through the development of improved multispectral self-defense obscuration systems

Table III–10 summarizes the demonstrations and systems found in the CBD and smoke and obscurants roadmaps. NBC modernization strategy emphasizes technology demonstrations incorporated into the front end of critical development programs.

TABLE III–10. CHEMICAL/BIOLOGICAL DEFENSE DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
No ATDs for CBD	**CBD—Contamination Avoidance** Laser Standoff Chemical Detection Technology Joint Service Modular Chemical Biological Detection Chemical Imaging Sensor Joint Service-Wide Area Detection Joint Service Chemical Biological Agent Water Monitor Battlefield Management/Joint Warning & Reporting Network Preplanned Product Improvement Liquid Surface Detector Low-Level Toxicology Biological Sample Preparation System for Biological Identification	**CBD—Protection (Individual and Collective)** Joint Service Chemical Ensemble Joint Service Collective Protection Advanced Adsorbents for Protection Applications **CBD—Decontamination** Joint Service Sensitive Equipment Decontamination Superior Decontamination System **Smoke & Obscurants** Millimeter-Wave Screening (STO) Distant Smoke Multispectral Smoke Pot (STO) Advanced Infrared Obscurants (STO)
Advanced Concept Technology Demonstration		
CBD—Contamination Avoidance Airbase/Port Biological Detection (Portal Shield) (includes chemical detection add-on)		

System/System Upgrade/Advanced Concept	
System/System Upgrade	**Advanced Concept**
Chemical Detectors	Wide Area Detector
Biological Detectors	Liquid Surface Detector
Individual Protection	Chemical & Biological Search
Collective Protection	Joint Chemical Ensemble II
Smoke & Obscurants	Next-Generation Joint Service General-Purpose Mask
	Electro-Optic System Marking Smoke

2 System Demonstrations

The Chemical/Biological Defense technology subareas are CBD—Contamination Avoidance, CBD—Protection, CBD—Decontamination, and Smoke and Obscurants.

a *CBD—Contamination Avoidance*

Contamination avoidance consists of chemical detection, biological detection, and battle management. Both remote early warning and point detection technologies are being developed.

AIRBASE/PORT BIOLOGICAL DETECTION (PORTAL SHIELD) ACTD (1996–02). The primary objective of this ACTD is to evaluate the military utility of an airbase or port perimeter biological detection capability and to develop operational procedures associated with that capability. An additional objective is to provide a residual interim capability adequate to detect, alarm, warn, dewarn, and identify a BW aerosol attack. The airbase or port residual capability will consist of a networked perimeter biological detection capability, laboratory presumptive identification capability, dewarning (unmasking) procedures, C^4I connectivity with base NBC reporting, oronasal half-mask market survey/test report, and biological sensor decontamination procedures and capability. This ACTD will also include a chemical add-on capability that will use available technology (M21 passive IR spectrometry and an automatic chemical agent detection alarm that uses ion mobility spectroscopy) to automatically detect and identify chemical threat agents in near real time (less than 30 seconds). Additionally, this chemical add-on will provide the CINCs with a capability to network legacy and emerging CB detectors, and will produce automated warnings and reportings for enhanced battlefield visualization and force protection as defined in *Joint Vision 2010.*

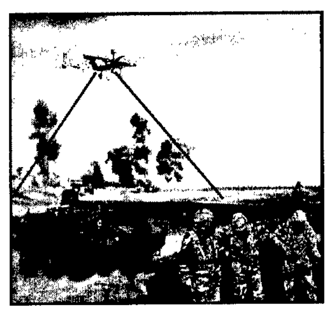
LASER STANDOFF CHEMICAL DETECTION TECHNOLOGY DTO (2001). Provides a standoff laser integrated chemical and bioaerosol detection capability for protection of fixed sites, reconnaissance, and other battlefield applications. FY01 will demonstrate a brassboard capability in field testing with sufficient laser power and detector sensitivity to detect chemical and biological agents at a dis-

tance of 20 km (a 400 percent increase from the FY96 baseline), and evaluate sensitivity for dusty chemical agent detection. This DTO supports Joint Service Chemical Warning and Identification LIDAR Detector, Joint Service NBC Reconnaissance System, and Airbase and Shipboard Chemical and Biological Defense.

JOINT SERVICE MODULAR CHEMICAL BIOLOGICAL DETECTION (JSMCBD) TD (2002–07). The JSMCBD will be the universal detector for the armed forces that fully integrates both point and remote sensors in one detector. This demonstration will feature miniaturized, multitechnology-based, fully automatic (in manned or unmanned mode), all-agent-capable (generic) detection with automatic warning and reporting linked to the theater C^4I system. This capability will provide the commander an all-encompassing CB assessment of the battlefield.

CHEMICAL IMAGING SENSOR (CIS) DTO (2001–02). This DTO will demonstrate a lightweight, wide-area, passive standoff imaging detection system capable of rapidly detecting chemical agent vapors for the purpose of contamination avoidance, reconnaissance, and facilities evaluation. The final system will operate at 360 Hz with a 256 × 256 focal plane array (FPA), and is scheduled for transition to development in FY03. This DTO will focus on development of ultra-high-speed interferometers, integration of off-the-shelf FPAs, and development of a signal processing algorithm. The CIS will allow rapid evaluation of large areas for CW contamination, and provide detailed information as to the position of a CW agent cloud. Current single-pixel designs have an extremely limited field of view (typically 26 m at a distance of 1 km). In addition, they cannot scan at sufficient speeds for proposed high-speed applications. The CIS will be capable of operating at fields of view at least 250 times greater than current systems. In addition, scan speeds will be increased by almost two orders of magnitude for extremely high-speed applications. The potential deployments include fixed sites, ground vehicles, unmanned aerial vehicles, helicopters, high and low aircraft, and even low-Earth-orbit configurations.

JOINT SERVICE-WIDE AREA DETECTION (JSWAD) TD (2001–06). This sensor will expand the capability of current passive interferometry and signal processing to allow long-range chemical imaging. The sensor will be capable of detecting known chemical agents and can be programmed to detect other militarily significant spectral data. It will also provide a visual display of the hazard area. Extended detection range capability will be provided for use on aircraft and high-altitude reconnaissance systems. The program will use design and performance data developed in Project Safeguard.



JOINT SERVICE-WIDE AREA DETECTION

JOINT SERVICE CHEMICAL BIOLOGICAL AGENT WATER MONITOR (JSCBAWM) TD (2000–03). This TD will demonstrate both an in-line (Air Force) and a portable-batch water test capability. JSCBAWM will detect chemical agents in accordance with the revised U.S. Army Surgeon General's requirements for chemical agents and also detect a range of waterborne biological agent contaminations down to parts per million. The system will rapidly evaluate water and provide a near-real-time alert if water becomes contaminated so that immediate action can be taken to prevent ingestion by warfighters.

BATTLEFIELD MANAGEMENT/JOINT WARNING AND REPORTING NETWORK (JWARN) PREPLANNED PRODUCT IMPROVEMENT (P^3I) TD (2002–03). This demonstration will build from the capabilities of off-the-shelf integration efforts of the interim JWARN program. This first step includes sensor links, a hazard prediction tool, and an automated NBC warning and report system into a CB Battlefield Management System. The tech base battlefield management effort will address the networking of

NBC sensors with relevant non-NBC battlefield sensors. The battle management capability must be compatible with the joint C^4ISR structure. The P^3I version will demonstrate seamless integration into the future digitized "common picture" of the battlefield. Included will be decision aid support modules and automation tools that provide a shared situational awareness of the hazard and allow real-time NBC defense synchronization. Advanced callback capabilities for split-based operations and a high-resolution digitized mapping capability are being pursued.

LIQUID SURFACE DETECTION TD (2002–05). This program will demonstrate an active and passive hybrid system for detection and identification of chemical agent liquid surface contamination. This effort will culminate in the development of a system for reconnaissance, contamination avoidance, and decontamination effectiveness evaluation.

LOW-LEVEL TOXICOLOGY TD (2001–05). Toxicology data support all commodity areas at all levels to include establishing requirements for protection, decontamination, and thresholds for detection. Toxicology data are required in their pure form and in the mixtures found in munitions and byproducts. Byproducts may result from degradation in the battlefield environment, decontamination treatments, or long-term storage. Simultaneously, a multiyear program to address the toxicology issues of low-level exposures to agents is being undertaken jointly by the medical and nonmedical programs. Congress has asked the Secretary of Defense for a plan to develop a 5-year research program to determine the effects of low-level exposures in order to guide the evolution of policy and doctrine in both medical and nonmedical CB defense.

BIOLOGICAL SAMPLE PREPARATION SYSTEM (BSPS) FOR BIOLOGICAL IDENTIFICATION DTO (2001–02). An advanced BSPS will be developed and demonstrated by 2001 for incorporation with leading-edge biological identification technologies. The advanced BSPS will be compatible with an array of agents of biological origin (ABOs) identification approaches under development for next-generation field biodetection systems. It represents and essential enabling technology for the success of these systems. The final product of this effort is intended to transition to Joint Biological Point Detection System Block II. When incorporated with advanced biological identification technologies, the technology being developed will expand the scope of detectable and identifiable ABOs, shorten the time required for sample analysis, ensure that a minimum and properly prepared sample load is analyzed, and reduce the associated logistics burden and the overall logistics footprint. The development of these technologies, along with concurrent advances in biological identification systems, will permit more rapid and reliable response (1) at a lower overall implementation investment to biological threats on the battlefield, and (2) in applications related to domestic preparedness, intelligence gathering, and treaty verification issues.

b *CBD—Protection*

CB protection includes technological efforts to provide protection for the individual warfighter as well as enclosures where groups of personnel could gain collective protection from the contaminated environment. Eye, respiratory, and percutaneous technology efforts are aimed at developing the next generation of eye and respiratory protection equipment and clothing ensembles for the 21st century warfighter.

JOINT SERVICE GENERAL-PURPOSE MASK

JOINT SERVICE CHEMICAL ENSEMBLE TD (2001–03). A variety of materials and materials technologies are being investigated to provide fully integrated percutaneous protection against CB agents in the

warrior's battledress ensemble. Integrated CB percutaneous protection may eliminate the need for a separate battledress overgarment. To accomplish this, protective materials must be resistant to agents without increasing the physiological burden (e.g., heat stress, moisture buildup) normally associated with wearing individual protection equipment or ensembles. Selectively permeable fabrics that will allow heat and moisture to escape while not allowing agents to permeate (i.e., selectively permeable membrane technology) will provide the soldier with enhanced percutaneous protection over carbon-impregnated materials used in the current battledress overgarment.

JOINT SERVICE COLLECTIVE PROTECTION TD (2001–04). This program was divided into two efforts in FY98: the Joint Transportable Collective Protection System (JTCOPS) and the Joint Collective Protection Equipment (JCPE). Several technologies will be investigated, including improved tentage materials and closures, improved sorbents, improved particulate filtration media, filter residual life indicator, regenerable vapor, and particulate filtration. Advances in tentage will demonstrate lighter weight, reduced cube, decontaminable, lower cost materials. Advanced filtration concepts will demonstrate reduced size and weight potential, improved filtration capability, elimination or reduction of filter change outs, and integration into enhanced environmental control units.

ADVANCED ADSORBENTS FOR PROTECTION APPLICATIONS TD (2001–04). Advanced adsorbent bed compositions will be developed to enhance the chemical agent filtration capabilities of current single-pass filters as well as regenerative filtration systems under development. Advanced adsorbent bed compositions for use in NBC filters will result in smaller, lighter-weight filtration systems with reduced logistical requirements, improved protection against toxic industrial materials and reduced combustibility. Smaller, lighter weight filters are especially desirable to address respirator needs for (1) improved face seal (less filter weight improves mask-to-face bond), and (2) improved weapons sighting (reduced filter size improves man-to-weapon interface). Development of noncombustible adsorbent beds is desirable to eliminate the possibility of a filter fire in the event of overheating resulting from malfunctioning of system components. In FY99, adsorbent materials and combinations of materials exhibiting the desired properties and performance were prepared. An agent sorption assessment was initiated.

c *CBD—Decontamination*

The goal for decontamination technologies is to develop effective, environmentally low-impact CB decontamination systems to neutralize or break down toxic materials without damaging the contaminated surface or affecting the performance of the equipment being decontaminated. Studies focus on the use of supercritical carbon dioxide, ozone, sorbents, solution decontamination, and enzyme-based systems.

ENZYME-BASED DECON

JOINT SERVICE SENSITIVE EQUIPMENT DECONTAMINATION (JSSED) TD (2001–03). [Note: This program is a merger of the former Aircraft Interior Decontamination Program and the JSSED. Based on different levels of maturity of these two programs, development is following separate milestones.] These demonstrations address two phases required to meet user-sensitive equipment decontamination needs. The user requires a multi-component system. The first is a component to remove CB

materials from small sensitive items, electronic components, and parts. One technical approach investigates the use of a closed-loop recirculating supercritical carbon dioxide system to remove CB materials. A second approach uses a nonozone-depleting fluorocarbon or fluorester solvent system to remove the contaminant from the surfaces. The second phase will demonstrate a means to decontaminate and detoxify CB agents in interior spaces containing electronic components and a variety of surfaces. Technical approaches focus on gaseous or plasma phase oxidation processes and hot air or other thermal treatment. These systems will provide additional capability to the user. They will eliminate the need for protective status while performing maintenance operations, render contaminated individual equipment and small electronics reusable after prior contamination, and provide the capability to decontaminate the interior spaces of aircraft, tanks, ships, and other vehicles.

SUPERIOR DECONTAMINATION SYSTEM TD (2006). The objective of this effort is to develop decontamination systems that supplement or replace existing systems used for all decontamination, including a general-purpose decontaminant to replace DS2 and aqueous bleach in thorough decontamination applications.

d *Smoke and Obscurants*

The smoke and obscurant strategy capitalizes on technologies capable of providing multispectral screening. These environmentally and logistically acceptable multispectral materials will counter enemy RSTA activities in broader ranges of the EM spectrum for self-defense, large-area coverage, and projected applications.

MILLIMETER-WAVE (MMW) SCREENING TD (2001–04). This demonstration will prove the feasibility of an MMW obscurant-generating system to prevent threat radars from observing, acquiring, targeting, and tracking friendly assets. The MMW TD will demonstrate up to a 90 percent reduction in material, logistics, and maintenance costs. This MMW module will expand the capability of the current M56 large-area smoke generator. Aerosol technology, chemical dispersion techniques, and dissemination mechanisms will be exploited.

DISTANT SMOKE TD (2001–02). This effort will demonstrate the delivery capability of an obscurant from a standoff position 3–10 km from the target area. Current concepts include the use of UGVs and UAVs. Creative packaging and dissemination will be employed to maximize success. Higher performing, low-cost, environmental friendly materials are needed to minimize logistical constraints.

MULTISPECTRAL SMOKE POT TD (2002–04). This demonstration will determine the feasibility of IR and MMW material dissemination from a smoke pot using propellant technology. A reasonably priced IR or MMW smoke pot currently does not exist because of low efficiency of the traditional (pyrotechnic and explosive) dissemination technologies. This will extend the current use of smoke pots to the IR and MMW portions of the spectrum.

ADVANCED INFRARED OBSCURANTS STO (2001–04). The thrust of this STO is to use novel material technology to find a higher performing obscurant material in the infrared (mid and far) region of the electromagnetic spectrum. By the end of FY01, particle characteristics of an ideal IR obscurant will be defined and the most efficient defeat mechanism for IR sensors will be determined. Other objectives from FY02 to FY04 include determining what commercial processes exist or can be modified to produce candidate materials; identifying cost drivers for material production; evaluating and selecting a new obscurant that will increase obscuring performance by a factor of

four; demonstrating a new obscurant screening material and a chamber method for evaluating its performance as an aerosol; and evaluating the applications of this advanced obscurant material in simulations to determine the percentage of increased survivability for the soldier. This technology will be applicable to IR screening smoke pots, grenades, artillery rounds, and vehicle self-protection. Its focus on increased performance could open the possibilities for an IR smoke pot, an IR hand grenade, and an IR screening artillery round. It would significantly reduce the logistics burden of a vehicle self-protection IR grenade.

3 Roadmaps

The NBC Defense program roadmap is comprised of contamination avoidance, both chemical (Figure III–31) and biological (Figure III–32) detection; protection, both individual and collective (Figure III–33); and decontamination (Figure III–34). The roadmap for smoke and obscurants is shown in Figure III–35.

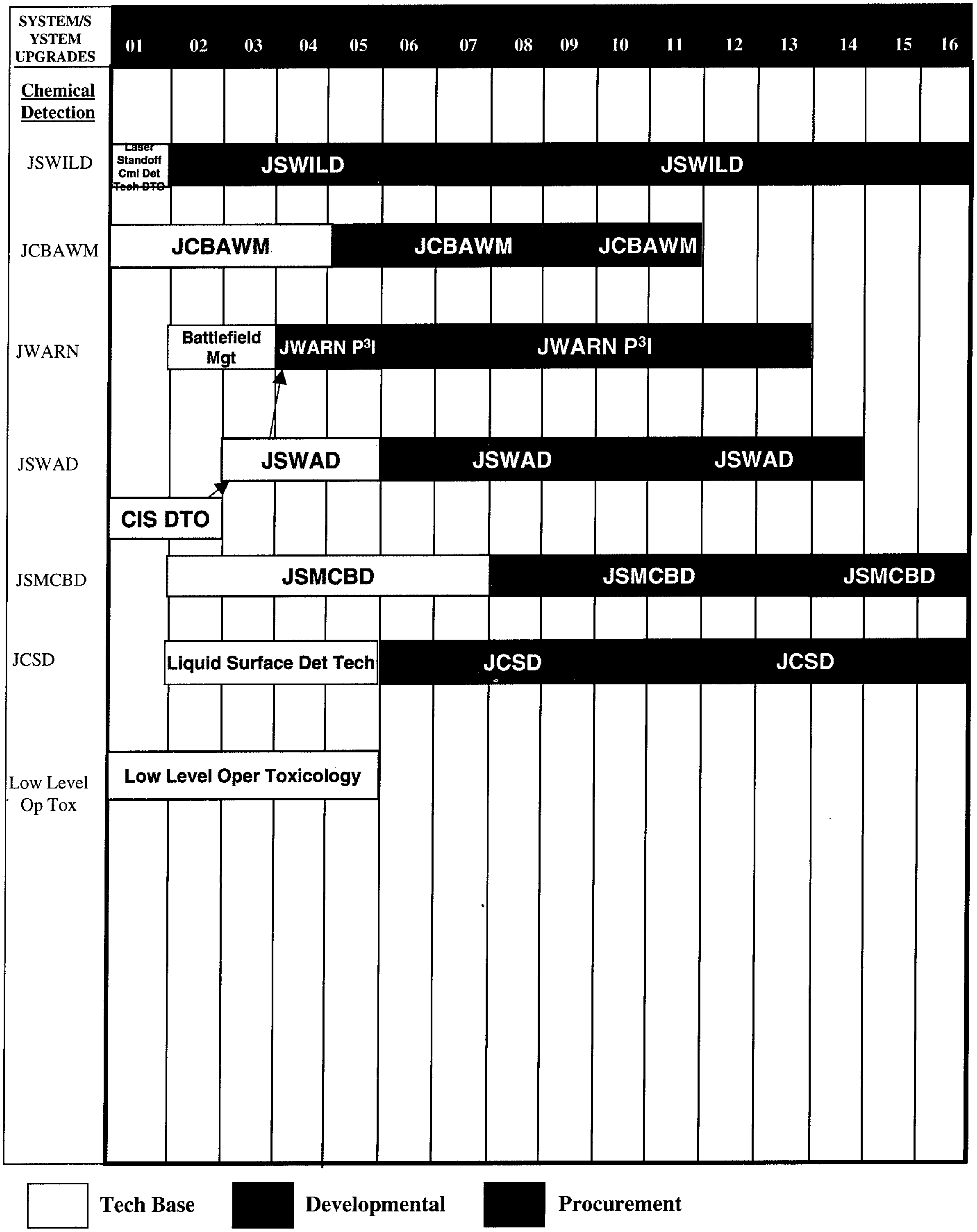


FIGURE III–31. ROADMAP—CONTAMINATION AVOIDANCE: CHEMICAL DETECTION

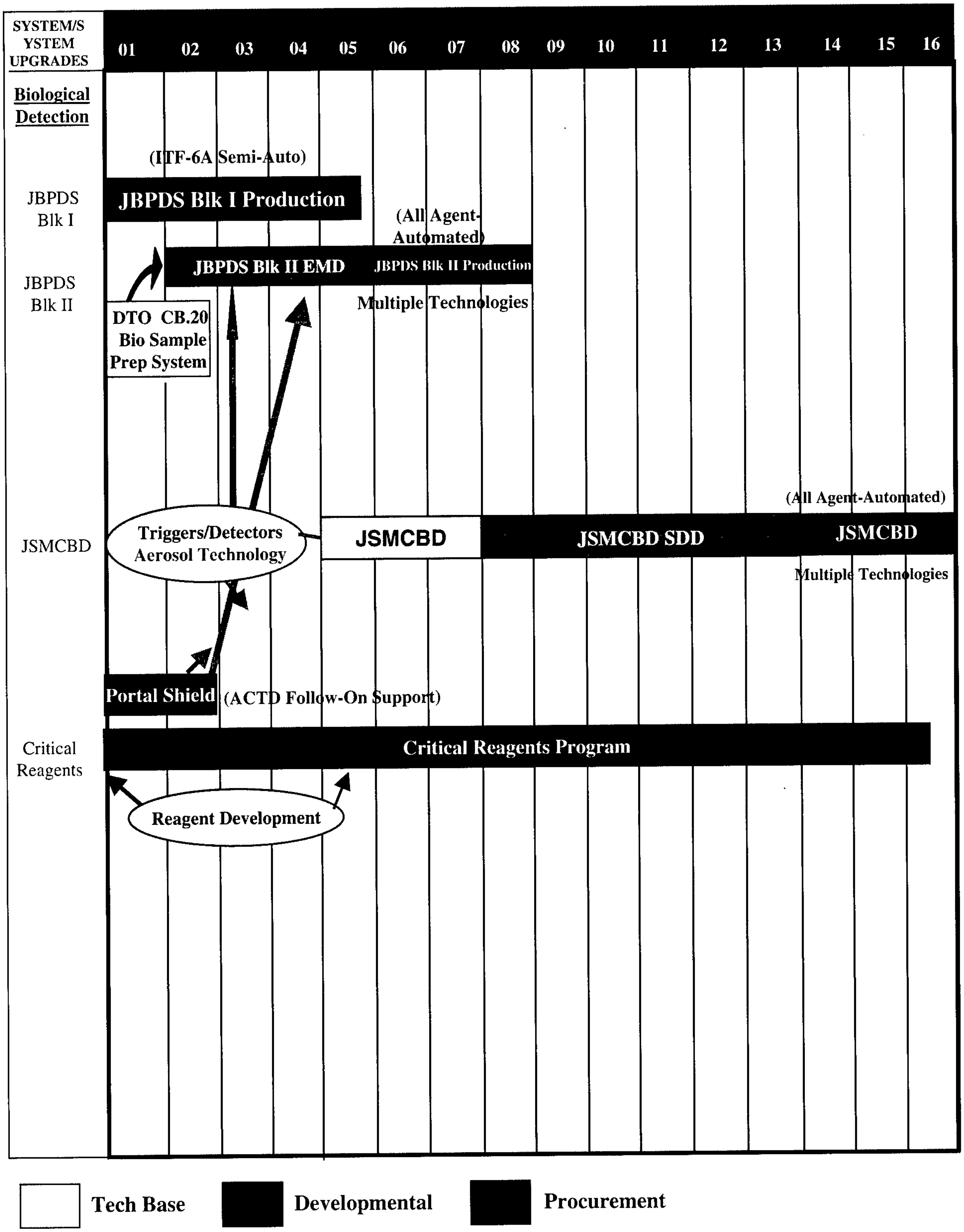


FIGURE III–32. ROADMAP—CONTAMINATION AVOIDANCE: BIOLOGICAL DETECTION

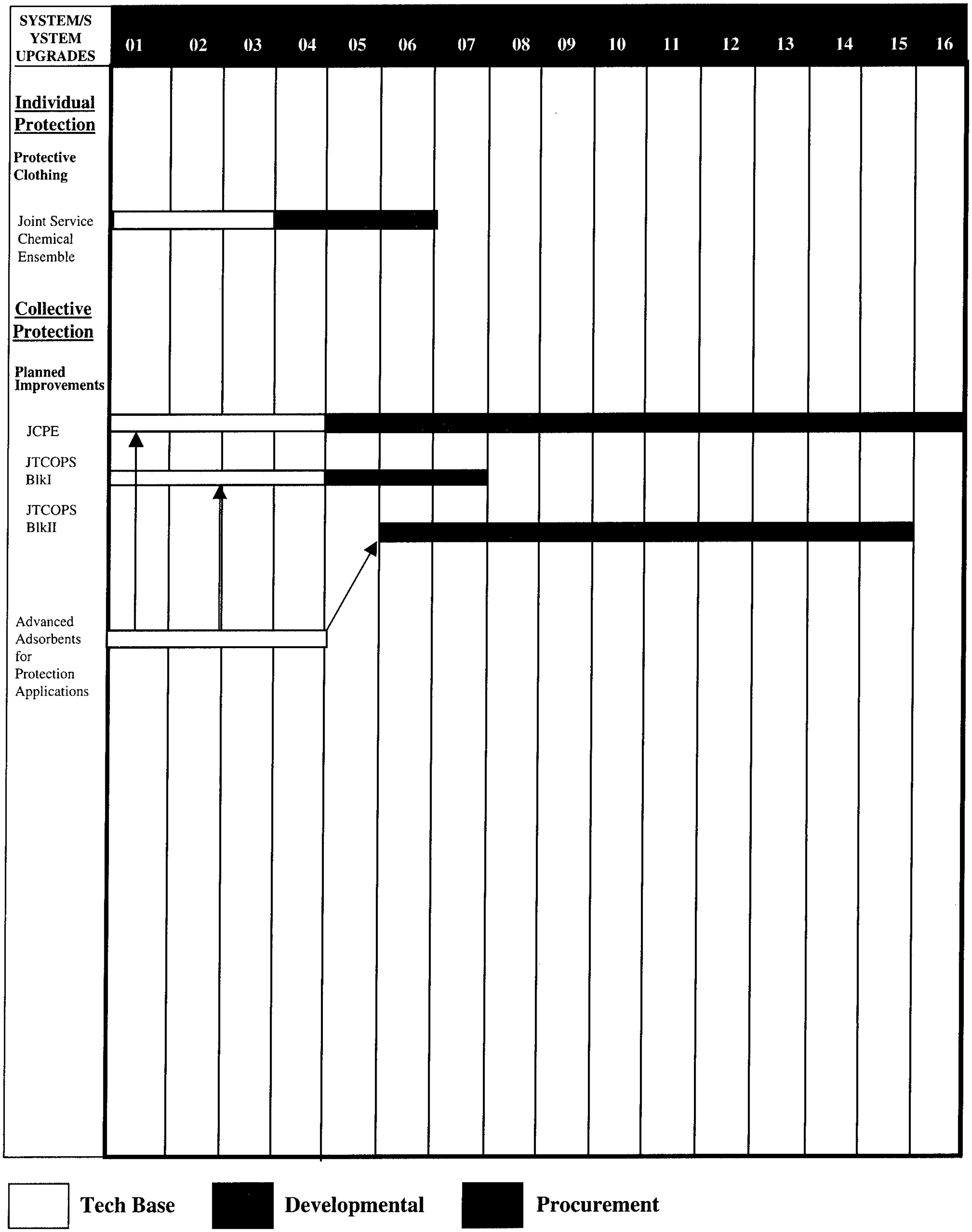


FIGURE III–33. ROADMAP—INDIVIDUAL AND COLLECTIVE PROTECTION

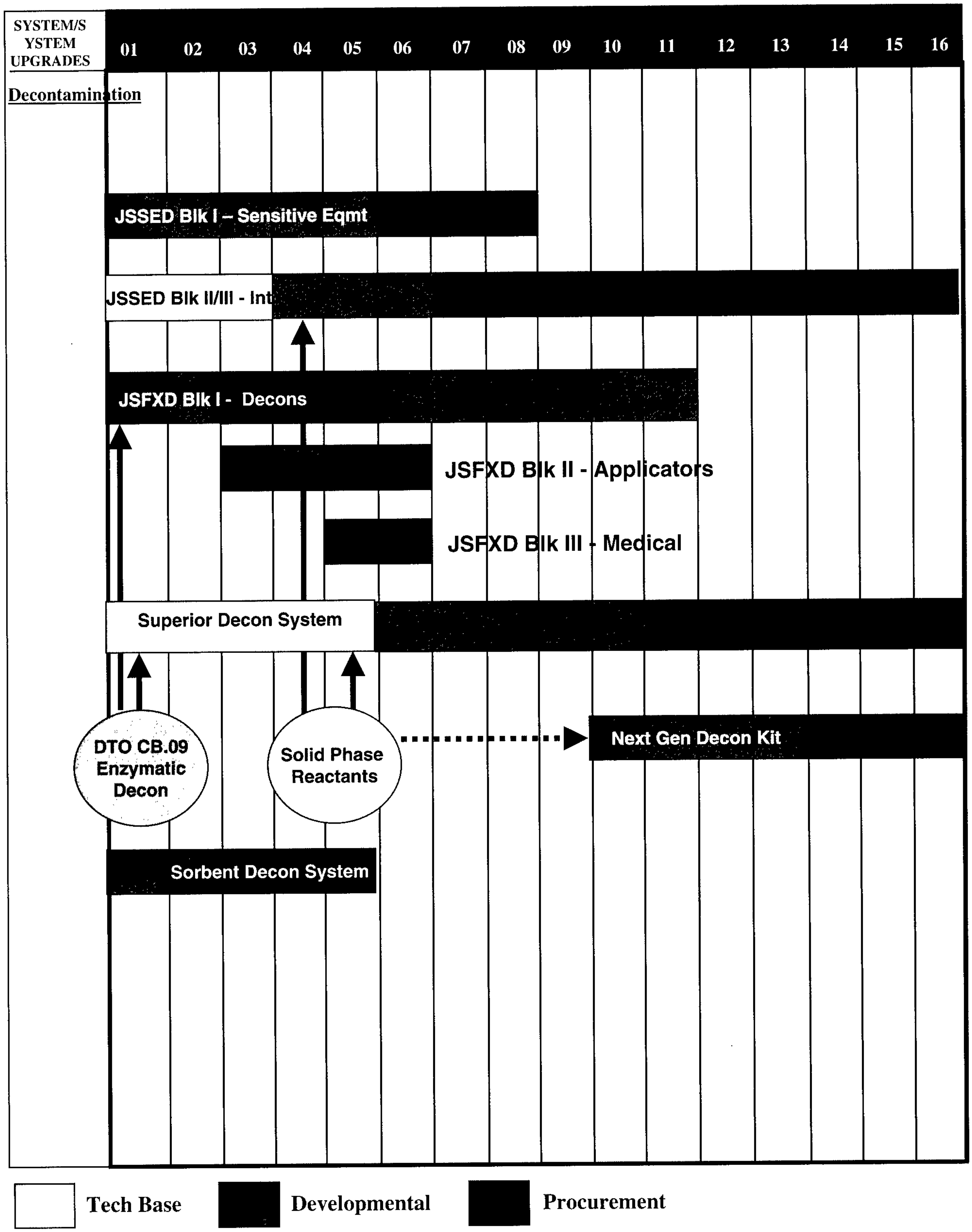


FIGURE III–34. ROADMAP—DECONTAMINATION

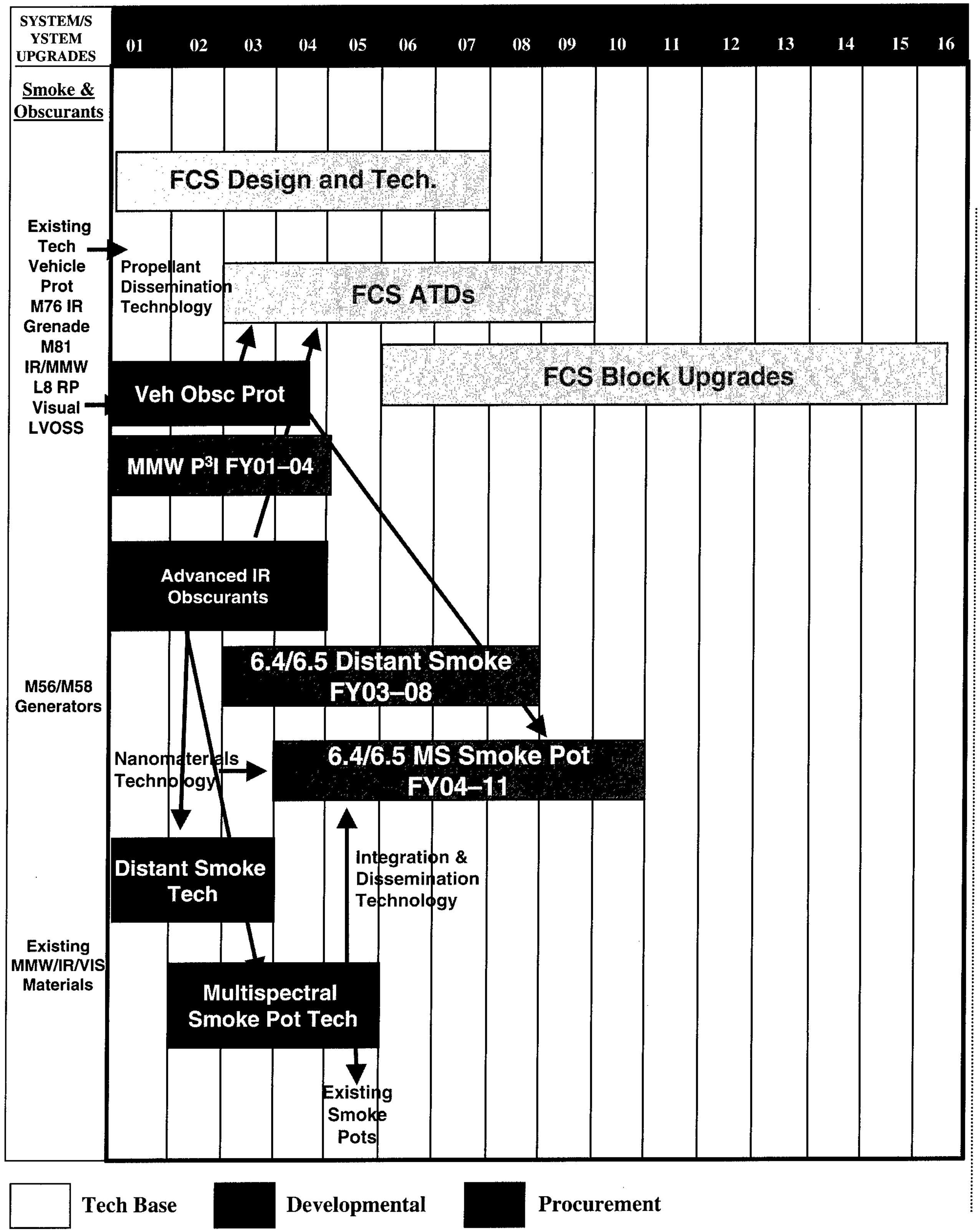


FIGURE III–35. ROADMAP—SMOKE AND OBSCURANTS

K AIR AND MISSILE DEFENSE

The mission of Air and Missile Defense (AMD) in the 21st century is to protect the force and selected assets from aerial attack, missile attack, and surveillance. The goal is to prevent enemy forces from targeting or shooting friendly forces from the air. To meet AMD mission requirements and fulfill AMD counterthreat capabilities, technology development to support the AMD force must focus on the concepts of the Army's vision for transformation to the Objective Force. The AMD force must be a strategically deployable, highly mobile and versatile force, and trained and equipped to deploy anywhere in the world on short notice; it must be highly lethal and capable of battlefield survival. AMD developments must also address the threat trends toward low-cost, high-payoff unmanned systems—tactical ballistic and cruise missiles, unmanned aerial vehicles (UAVs), and rockets.

With many nations acquiring technologically advanced, highly lethal weapons such as ballistic missiles, the AMD force will face a future threat that is increasingly challenging and diversified. Adversaries will closely monitor U.S. AMD technologies and capabilities, attempting to capitalize on any weaknesses. Although traditional air threats will still exist in the world of tomorrow, the changing complexity and focus of the AMD threat will require AMD forces to be capable of dominating the battlespace while continuing to support force projection operations in major regional contingencies, protect the United States in coordination with joint air defense systems, and execute military operations other than war.

AMD is inherently a joint activity, and accordingly, the preponderance of AMD effort by Army organizations is led and funded by the Ballistic Missile Defense Organization and the Joint Theater Air and Missile Defense Organization. Army S&T plays a big role in supporting those joint leads as well as integrating AMD functionality into Army-led systems—like FCS—whenever feasible and appropriate.

The AMD challenge is the orderly transformation of today's force into an economical objective force capable of achieving full-spectrum dominance, defeating tomorrow's threat. Successful execution of future operations will require increased emphasis on planning and conducting joint and multinational operations. Because AMD is a joint operation, Army AMD forces must function as an integrated component of the joint and multinational AMD forces to achieve full spectrum dominance.

The AMD area is focusing its technology development efforts on improvements in the areas of sensors, RF target discrimination and recognition, and interceptors. This section describes several 6.3 technology programs supporting AMD. Specific demonstrations include the Multifunction Staring Sensor Suite ATD, which provides a sensor suite for target identification; the Multimission Radar and the Overhead Passive Sensor Technology for Battlefield Characterization, which support radar sensor improvements; and the Atmospheric Interceptor Technology, the Strapdown Seeker, the Kill Assessment, the Advanced Windows, the Advanced Master Frequency Generator, and the Radio Frequency Target Discrimination and Recognition programs, which provide improvements in the interceptor subarea.

1 Modernization Strategy

The AMD modernization goal is to provide an affordable AMD force capable of performing missions that support the joint forces commander in execution of the national security strategy and national military strategy that meets the transformation goals of the Army and the Objective

Force while maintaining full-spectrum dominance. The AMD modernization strategy emphasizes a family of systems to implement an overarching, tiered defense and stresses interoperability in a joint and multinational environment. The strategy capitalizes on combinations of system improvements and development of new systems to maintain the technological edge and overmatch the evolving threat.

Table III–11 summarizes demonstrations and systems. Modernization of AMD depends on the development of these key systems for air defense coordination. Many of the systems denoted below are described in more detail elsewhere in this section. Their inclusion here reflects critical AMD functionality to be designed in and tested.

TABLE III–11. AIR AND MISSILE DEFENSE DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Information Collection Multifunction Staring Sensor Suite	**Information Collection** Overhead Passive Sensor Technology for Battlefield Characterization (STO) **Radar Sensors** Multimission Radar (STO)	**Interceptors/Seekers** Atmospheric Interceptor Technology Program Strapdown Seeker Effort Kill Assessment Technology Advanced Windows Technology Effort Advanced Master Frequency Generator Effort Radio Frequency Target Discrimination and Recognition
System/System Upgrade/Advanced Concept		
System Upgrade Patriot Advanced Capability Theater High-Altitude Area Defense Ground-Based Radar Bradley Linebacker Short-Range Air Defense	**Advanced Concept** Medium-Extended Air Defense System	

2 System Demonstrations

The AMD technology subareas are Information Collection, Radar Sensors, and Interceptors/Seekers.

a *Information Collection*

Information collection systems for AMD are targeted against all AMD airborne threats. They embody modular, scalable, multisensor capabilities that combine electronic intelligence, communications intelligence. and electronic attack.

MULTIFUNCTION STARING SENSOR SUITE (MFS^3) ATD (1998–01). The MFS^3 ATD will provide a compact, affordable sensor suite for long-range, noncooperative target identification; low-signature target acquisition; mortar/sniper fire location; and air defense targeting against low signature UAVs and long-range helicopters. (See Section III–E, "ISR&EW," for additional information.) *Supports:* FCS, Bradley Stinger Fighting Vehicle—Enhanced.

OVERHEAD SENSOR TECHNOLOGY FOR BATTLEFIELD CHARACTERIZATION STO (2000–03). This effort will develop and demonstrate advanced sensor technologies for wide area battlefield force detection, discrimination, and target identification in near real time and reduce platform data communications downlink and ground processing requirements. Technologies focus on defining passive optical sensor spectral, polarimetric, and focal plane array requirements. This program provides

opportunities for the Army to define operational and technical requirements for next-generation space spectral sensors and associated ground processing capabilities in support of the Army warfighting goals. *Supports:* PEO–AMD, Lower Tier Air and Missile Defense Project Office, THAAD Project Office, PEO–Tactical Missiles, ATACMS/BAT Project Office.

b *Radar Sensors*

The radar sensor subarea provides the capability for all-weather detection, location, and recognition capability of significant military AMD targets. Requirements for radar are moving beyond detection to target classification, which is now driving radar performance to high-resolution, precisely registered n-dimensional measurement capability. This subarea provides AMD the capability to advance technologies in the radar sensor area.

MULTIMISSION RADAR (MMR) STO (2002–06). The MMR technology program will enable the Army to rapidly deploy a single sensor that will perform multiple missions (e.g., AMD engagements of rockets, artillery, mortars, UAVs, rotary- and fixed-wing aircraft, and counterfire target acquisition). (See Section III–E, "ISR&EW," for additional information.) *Supports:* PEO–AMD, PM–SHORAD, PM–Air Traffic Control, SOCOM, PM–Firefinder, the Marine Corps.

c *Interceptors/Seekers*

The interceptor subarea relies on IR, RF, or a combination of IR and RF sensing capabilities to acquire, track, recognize, discriminate, and home in on threat targets. The efforts discussed in this area provide analysis, algorithm development, evaluation, tools, and models for interceptor technology development.

ATMOSPHERIC INTERCEPTOR TECHNOLOGY (AIT) PROGRAM TD (1999–05). This program will provide the AMD community with a higher confidence to defeat the evolving threats of the future, including chemical and biological weapons of mass destruction, by identifying and developing technologies to support P^3I components and subsystems for incorporation into AMD systems. High-velocity intercepts are essential to maintain sufficient battlespace, lethality, and coverage and footprint performance. However, high-velocity flight provides severe aero-optic, aerodynamic, aerothermal, and structural requirements to the interceptor. AIT's extensive technology development and ground testing program is resolving the critical issues associated with high-velocity, low-altitude flight. *Supports:* PAC–3, MEADS, THAAD.

STRAPDOWN SEEKER EFFORT TD (2000–03). This effort will develop advanced strapdown seeker technologies that body fit the seeker to the missile and steer and stabilize LOS without moving the entire seeker, thus using fewer parts and allowing a smaller aperture having a smaller weight and volume. The seeker will be capable of performing optimum detection, tracking, and aimpoint selection against current and advanced threats that operate within the atmosphere, considering target characteristics, backgrounds, and system performance. *Supports:* PAC–3, MEADS, THAAD.

KILL ASSESSMENT TECHNOLOGY (KAT) TD (1999–05). The KAT program provides for sensor data collections of interceptor tests, post-intercept scene analysis, and algorithm development with two objectives: (1) to enable ballistic missile defense (BMD) systems to assess target kills in support of shoot-look-shoot architectures, and (2) to increase understanding of post-intercept scene to avoid loss of battlespace in both shoot-look-shoot and shoot-shoot architectures. The program's primary goal is to identify the most useful type of data and the particular types of algorithms

required to meet this operationally required real-time assessment and to provide prototype algorithms to BMD system developers. The program collects pertinent full- and subscale test data, which is severely lacking at this time. Effective real-time kill assessments allow for a reduction in missile inventory. A secondary goal of the kill assessment program is to provide data analysis and techniques for use in mitigating the effects of intercept fragments and debris on BMD systems' operational effectiveness. The presence of fragments and debris in the battlespace has the potential to seriously stress BMD radar resources. *Supports:* THAAD.

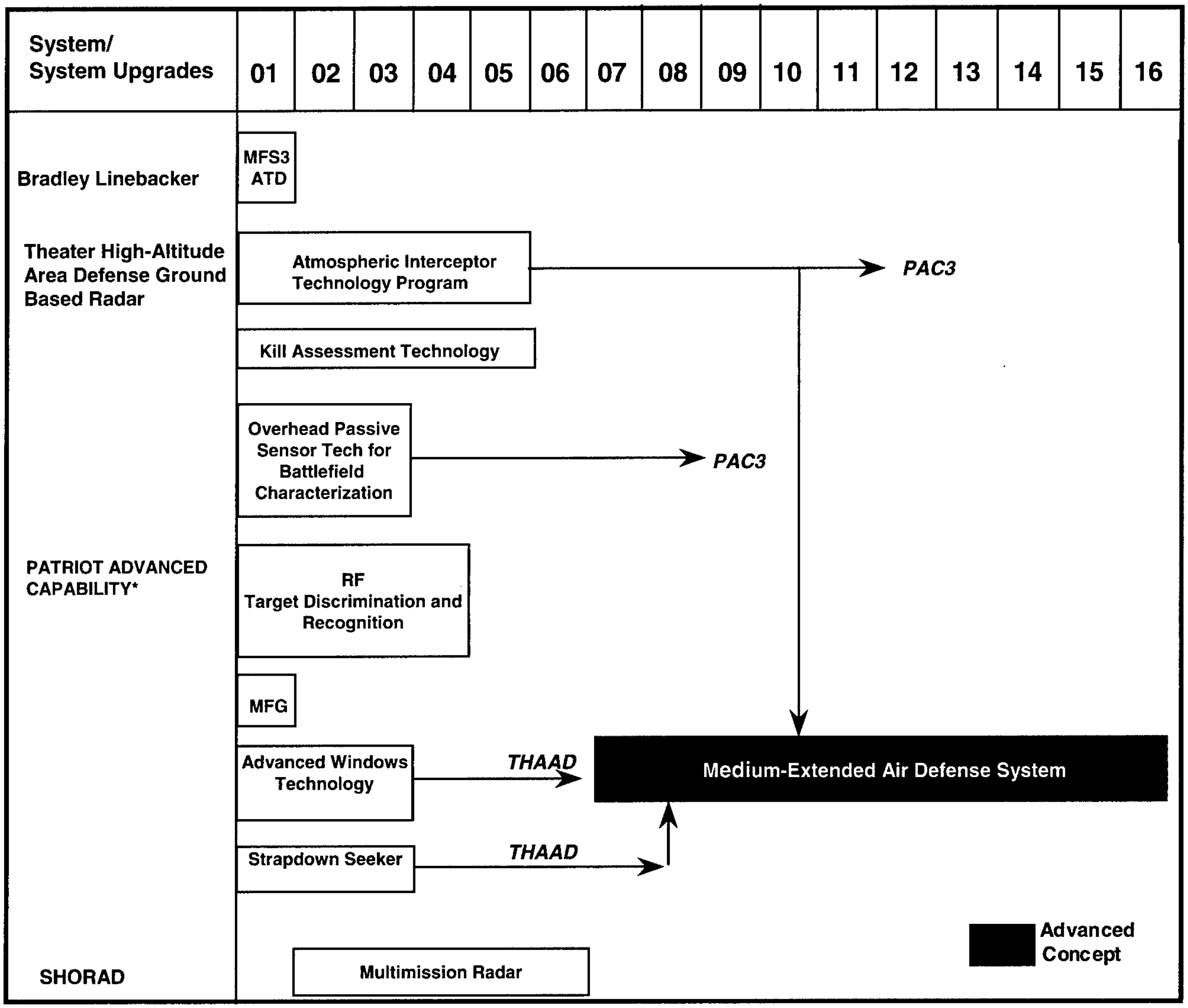
ADVANCED WINDOWS TECHNOLOGY EFFORT TD (1999–03). This effort will facilitate the development of advanced designs to optimize seeker thermal and optical viewing performance and to minimize weight and costs. These designs will include the window, window frame, coolant, and coolant system as required. These designs will be developed for IR-only missile systems as well as dual-mode IR/RF systems. *Supports:* PAC–3, MEADS, THAAD

ADVANCED MASTER FREQUENCY GENERATOR (MFG) EFFORT TD (1999–01). This effort will reduce the cost of the current MFG without degrading performance and assess additional improvements that will provide performance enhancements. Improvements over the current MFG will include (1) component count reduced from 318 to 155, (2) weight reduced from 2.44 kg to less than 2 kg, (3) number of millimeter-wave amplifiers reduced from 12 to 7 resulting in lower phase noise, and (4) power consumption reduction by 25 W. An advanced, lower cost MFG has been identified by PM–Patriot as its highest technology need, since the MFG is the single most expensive component within the seeker and the seeker is the most expensive subsystem within the missile. *Supports:* PAC–3.

RADIO FREQUENCY TARGET DISCRIMINATION AND RECOGNITION TD (2000–04). This effort will provide unique abilities in the areas of radar analysis, real-time algorithm evaluation, real-time architecture evaluation, and real-time testing using raw and simulated field data for handling diverse theater ballistic missile threats. This effort will provide support to PAC–3 in assessment, discrimination, interceptor guidance, and aimpoint selection. It will further performing threat characterization for algorithm development and performance testing as well as support PAC–3 risk reduction and design requirements. *Supports:* PAC–3.

3 Roadmap

Figure III–36 presents the AMD roadmap.



* System Upgrade

FIGURE III–36. ROADMAP—AIR AND MISSILE DEFENSE

L ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY

The Army is facing a changing threat with varied degrees of sophistication as it enters the 21st century. Given this dynamic threat, the engineering, combat construction, mobility and countermobility (ECCM&C) mission area continues to play a key role as a critical enabler for the Objective Force. Recent military operations have demonstrated the need for robust ECCM&C capabilities.

The ECCM&C mission area consists of the five major battlefield functions of mobility, countermobility, survivability, sustainment engineering, and topographic engineering. Each function is necessary to conducting successful operations throughout the operational continuum, whether fighting a major regional conflict or providing military assistance in support and sustainment operations (SSO). Applying technological advancements to modernize these functions enhances the ability of the combined arms commander to conduct opposed entry, sustained land combat, and SSO to achieve decisive victory. This section focuses on ECCM&C S&T programs providing systems and system upgrades in support of combat maneuver modernization to achieve full-spectrum dominance throughout the battlespace.

Current threat land mines are inexpensive, readily available, and capable of destroying multi-million-dollar weapon systems and killing or injuring U.S. Army personnel. During recent worldwide conflicts, mines have been employed in large numbers and, in many cases, without regard to standard convention. Microelectronics and advanced warhead designs are leading to a new class of cheap smart mines that will lead to new levels of lethality. Technology to counter this threat has been unable to keep pace with the proliferation of mines, particularly in the detection of low-metal, plastic-cased antitank and antipersonnel mines.

1 Modernization Strategy

The ECCM&C modernization strategy emphasizes investment in S&T programs leading to ATDs, ACTDs, battle laboratory experiments, and AWEs. Technological advances will be incorporated more often into systems via upgrades than by creating entirely new systems.

Of the ECCM&C battlefield mission areas, mobility and survivability are currently receiving a new focus in S&T due to the ever-increasing mine and terrorist bomb threats. Effective and responsible mine warfare obstructs the mobility and survivability of opposing forces and creates conditions favorable to the mine user without inflicting needless casualties on noncombatants. Mine warfare constitutes a significant element in armed conflict at all levels of intensity and is critical to early entry forces, which may be overmatched. Mines are cheap, lethal, psychologically disruptive, and readily available, and they will be encountered on all future battlefields. The result is that relatively cheap mines employed quickly and in quantity can immobilize a powerful force.

Munitions and countermine development includes all efforts pertaining to the development or improvement of wide area munitions and all efforts pertaining to detecting, marking, breaching, neutralizing, or clearing land mines. The detection efforts are aimed at improving capabilities in handheld, vehicular-mounted, and airborne applications. The objectives for handheld and vehicle-mounted systems are to improve the detection rate and to reduce the false-alarm rate for antipersonnel land mines in the handheld systems, and for antitank mines in the vehicle-

mounted systems. In airborne detection, the objective is to develop technologies that will result in lightweight sensor packages for employment on UAVs.

The challenges for mine detection are high rates of detection while maintaining OPTEMPO and continued reduction of false alarms. The challenge for neutralization and minefield breaching is the requirement for greater than 90 percent neutralization for all land mines.

Specific challenges are:

- Increase probability of detection (P_d) for teleoperated systems
- Combine detection and neutralization capability
- Employ autonomous and semiautonomous robotics for mine neutralization
- Reduce false-alarm rate.

Table III–12 summarizes the systems, system upgrades, advanced concepts, TDs, ATDs, and ACTDs found on the ECCM&C roadmap.

TABLE III–12. ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Mobility Enhanced Coastal Trafficability & Sea State Mitigation	**Mobility** Lightweight Airborne Multispectral Minefield Detection (STO) Mine Detection & Neutralization for Future Combat Systems (STO) Mine Detection False Alarm Reduction for Increased Operational Tempo (STO) Advanced Minefield Detection Sensors (STO)	**Countermobility** Area Denial Systems (STO) **Survivability** Signature Management & Deception Technologies (STO) **Topographic Engineering** Digital Topographic Support System
Advanced Concept Technology Demonstration		
Sustainment Engineering Joint Area Clearance **Topographic Engineering** Rapid Terrain Visualization		

System/System Upgrade/Advanced Concept	
System Ground Standoff Minefield Detection System **System Upgrade** Digital Topographic Support System/Quick-Response Multicolor Printer Signature Management & Deception Technologies	**Advanced Concept** Lightweight Airborne Multispectral Minefield Detection Mine Detection & Neutralization for Future Combat Systems Area Denial Systems

2 System Demonstrations

The ECCM&C technology subareas are Mobility, Countermobility, Survivability, Sustainment Engineering, and Topographic Engineering.

a *Mobility*

Engineers enhance friendly freedom of maneuver by detecting, breaching, marking, and reporting mines and other obstacles; bridging gaps; constructing combat roads and trails; and performing forward aviation combat engineering operations. S&T programs focus on integrating countermine capabilities through live and simulated experiments. Integrating countermine technology with C^4I enhances the Army and Marine Corps commanders' mobility, survivability, situational awareness, and agility.

LIGHTWEIGHT AIRBORNE MULTISPECTRAL MINEFIELD DETECTION (LAMD) STO (1998–03). This effort will investigate novel sensor and system technologies (3- to 5- and 8- to 12-μm staring focal plane arrays, passive polarization, multi- and hyperspectral imaging, synthetic aperture radar, millimeter-wave radar, electronic stabilization) to develop a lightweight airborne standoff minefield detection capability for tactical operations. The system will detect buried nuisance mines on unpaved roads and surface, buried patterned, and scatterable minefields. *Supports:* Airborne Standoff Minefield Detection, Objective Force.

FUTURE COMBAT SYSTEMS MINE DETECTION AND NEUTRALIZATION STO (2001–03). The objective of this STO is to investigate, develop, and evaluate forward-looking sensor technologies, signal processing techniques, and mine neutralization techniques applicable to the detection and neutralization of on-/off-route surface and buried antitank mines. Goals are the detection and location of mines at distances 10–30 meters in front of the host vehicle at a 15–20-kph rate-of-advance and mine neutralization goals of P_k = 90–95 percent, standoff of 10–50 meters, and rate-of-advance of 10–20 kph. FCS mine detection and neutralization will be designed as a modular system for bolt-on integration onto FCS vehicle platforms, avoiding the need for specialized overpass vehicles and following confirmation sensors. This program will also pay particular attention to total life-cycle costs, sustainability, and maintainability. In FY03, the detection prototypes and neutralization breadboard hardware will be evaluated prior to the final technology demonstration. *Supports:* FCS.

FALSE ALARM REDUCTION FOR IMPROVED OPERATIONAL TEMPO (OPTEMPO) STO (2001–04). This STO will dramatically reduce false-alarm rates associated with mine detection by leveraging DARPA's advancements in detection techniques such as nuclear quadrupole resonance. These sensors, in combination with other sensors, will permit a significant increase in rates of advance. Route clearance will be faster and less time will be wasted dealing with "empty holes." The sensors will be integrated with advanced signal processing techniques, automatic target recognition algorithms, and sensor fusion on a single platform for final demonstration in FY04. *Supports:* Ground Standoff Minefield Detection System (GSTAMIDS) P^3I.

ADVANCED MINE DETECTION SENSORS STO (1997–01). Ongoing handheld and vehicle-mounted mine detection programs use multisensor approaches to achieve capability and performance enhancements beyond that of the AN/PSS–12 metallic mine detector for detection of both metallic and low-metal content mines. However, system performance, especially against small low-metal content mines, requires improvement in many clutter operational environments. Since the inception of these programs, new sensors and data analysis techniques have been proposed or investigated, which overcome many of the deficiencies of current mine detection approaches. The objective of this program is to develop and field evaluate novel sensor technologies and signal processing techniques to overcome current deficiencies specifically in detecting low and nonmetallic content mines, reducing false-alarm rates and classifying detected targets. These novel sensor technologies and signal processing techniques will augment or potentially replace current handheld and vehicle-mounted detection sensors or algorithms. Technical goals are 98 percent P_d with false-alarm rates less than 0.01 per square meter. *Supports:* GSTAMIDS P^3I, Handheld Standoff Mine Detection System.

ENHANCED COASTAL TRAFFICABILITY AND SEA STATE MITIGATION ATD (1998–02). This ATD will enable offshore ship offloading operations to continue during sea state 3 conditions, a capability that does not presently exist, but is vital to the Army's ability to meet present and future (force projection) sustainment requirements. It will also demonstrate technology developed to minimize

logistics burdens, construction time, and engineering equipment needed to conduct logistics operations over the shore. *Supports:* The RML (for additional information, see Section III–M, "Logistics.")

b *Countermobility*

Engineers impede the enemy's freedom of maneuver by disrupting, turning, fixing, or blocking his movement through obstacle development and terrain enhancement. S&T programs are integrating microelectronics, signal processing, and advanced intelligence into a controlled network of mine warfare systems.

AREA DENIAL SYSTEMS (ADS) STO (1998–01). This program will demonstrate the capability of self-contained, semiautonomous, long-standoff munitions that can defend an area by defeating, disrupting, and delaying vehicles that enter into its battlespace. The ADS concept provides the FCS with a countermobility capability to improve its survivability. ADS will allow FCS to shape the battlespace and protect its flank with a system that is more logistically efficient and effective than current barrier systems. This system will enhance other weapon systems in a manner similar to that achieved by land mines today, but without the postwar civilian mine threat and the demining problem. Component technologies that address the concepts of moving munitions and side-attack munitions for target engagement, advance queuing and tracking sensing technology, and efficient new warheads will be fabricated and tested. *Supports:* Next-Generation of Scatterable Munitions.

c *Survivability*

Engineers reduce friendly force vulnerability to enemy weapon effects through rapid fabrication of protective structures, terrain alteration, and concealment. S&T programs are focused on upgrades to the low-cost, low-observable (LO) camouflage systems. These systems provide the means to avoid being detected and hit. The upgrades are designed to reduce or eliminate visual, UV, near IR, thermal IR, and radar waveband signatures of mobile and stationary assets. The goal is to counter the highly sensitive reconnaissance, intelligence, surveillance, and target acquisition threat sensors in all parts of the EM spectrum. Signature control will be achieved through integration of passive, reactive, and active LO systems.

Field fortifications research is conducted by the Corps of Engineers Waterways Experiment Station (WES) for all of DoD. The focus of these efforts is on design of protective structures to defeat advanced munitions (bunker busters) and unconventional munitions (car bombs), the capture of commercial technology, and the identification of high-payoff protection techniques.

SIGNATURE MANAGEMENT FOR FUTURE COMBAT SYSTEMS STO (1998–06). Demonstrations are scheduled during FY01–06 for upgrades to camouflage and deception systems, including the advanced signature management and deception system for the tactical operations center, semimobile assets, the ultra-lightweight camouflage net system–general purpose (ULCANS–GP), and the standardized camouflage paint pattern (SCAPP). Technologies supporting the demonstrations include advanced electronic deception, adaptive coatings, and optimized multispectral coatings and patterns. *Supports:* ULCANS–GP P^3I, Multispectral Camouflage System for Mobile Equipment, SCAPP.

d *Sustainment Engineering*

Engineers support force sustainment by maintaining, upgrading, and constructing lines of communication and facilities; providing construction support and materials; and performing area damage assessment. Sustainment-related R&D products and tools will include rapid infrastructure assessment capabilities; generation and allocation of engineer resources to meet new construction, repair, or upgrade requirements; and enhanced visualization technologies.

JOINT AREA CLEARANCE (JAC) ACTD (2001–04). This candidate ACTD will evaluate the military utility of incorporating evolutionary technology into mobility sustainment operations to support full-spectrum dominance by U.S. military forces. Mobility sustainment affords the warfighter maneuverability to support unimpeded movement of critical military supplies throughout the battlespace. Mobility sustainment operations are widening the initial minefield breach, maintaining avenues of advance, and area clearance. The specific JAC ACTD technologies that will be evaluated include nonmilitary humanitarian demining technology, landmine detection, clearing, and unexploded ordnance disposal technologies. The JAC ACTD will also provide enhanced situational awareness by incorporating digital tracking of obstacles into the Global Command and Control System. The JAC ACTD has received support from AMC and TRADOC. The U.S. Joint Forces Command is the CINC sponsor. Warfighter exercises and scenarios are being identified and developed with the Maneuver Support Battle Laboratory for the ACTD.

e *Topographic Engineering*

Topographic engineers provide timely, accurate knowledge of the battlefield landscape, enabling terrain visualization for commanders and staffs at all echelons throughout the operational continuum to better understand the effects of terrain on their planned operations. Knowledge of the battlefield consists of information in narrative or graphic format describing or portraying the effects of terrain and climate on military operations. The ability of the commander to understand the impact of terrain and varying climatic conditions before the battle will aid him in determining optimal courses of actions. Terrain information developed or maintained by Army engineers provide the basic terrain reference for land and air forces as well as for other DoD agencies.

There are topographic engineering S&T programs for terrain data generation, exploitation and dissemination, geospatial database management, real-time positioning and navigation techniques, and improved tactical terrain and environmental decision aids. Key to battlefield awareness and crisis response is the development of technologies to support the rapid production and dissemination of imagery-derived topographic products. Advances in microelectronics, knowledge-based systems, and signal processing techniques, coupled with the proliferation of geospatial data into every Army system make topographic engineering sciences an extremely dynamic field.

DIGITAL TOPOGRAPHIC SUPPORT SYSTEM (DTSS) TD (1995–01). The DTSS, which began fielding in June 1998, provides a tactical capability to support the commander further with the latest in topographic technology. Additional fieldings in the DTSS will continue through FY01 at a minimum, with a potential for continuing fieldings in the following years. The P^3I program will provide for periodic increases in functionality, providing leading-edge geospatial and imagery exploitation capabilities to the topographic engineers.

RAPID TERRAIN VISUALIZATION (RTV) ACTD (1997-01). The RTV ACTD will integrate and demonstrate the capability to rapidly collect and process high-resolution digital terrain elevation data needed

to accurately represent the 3D battlefield; basic feature data such as roads, rivers, and vegetation required for military planning and analysis; and corresponding high-resolution imagery for photo-realism. These data are the essential foundation for battlefield visualization and support other missions such as crisis response and contingency operations. The focus of the RTV ACTD will be on source collection, data generation, and transformation of digital topographic data. TRADOC has established operational area and timeliness requirements for collection and generation of these digital terrain products. Specifically, the ACTD will collect, process, and generate Level III (10-meter post spacing) topographic data over a 90- by 90-km square area, with inserts of higher resolution Level IV (3-meter spacing) or V (1-meter spacing), in 72 hours. Situation databases, integrated with current terrain databases, provide the commander a dynamic, 3D visualization of his battlespace, enhancing mission planning and rehearsal, course of action analysis, and post-mission analysis capabilities. The ACTD leverages technologies developed by government and industry. These technologies are integrated in the Joint Integration and Evaluation Center (JIEC) and analyzed to determine their effectiveness. The ACTD has established testbeds at the XVIII Airborne Corps and III Corps to ensure continual feedback on the military value of selected capabilities, whose maturity has been demonstrated in the JIEC. Leave-behind capabilities will be provided to the XVIII Airborne Corps beginning in FY99 and supported through FY01.

3 Roadmap

The roadmap for ECC&C is shown in Figure III–37.

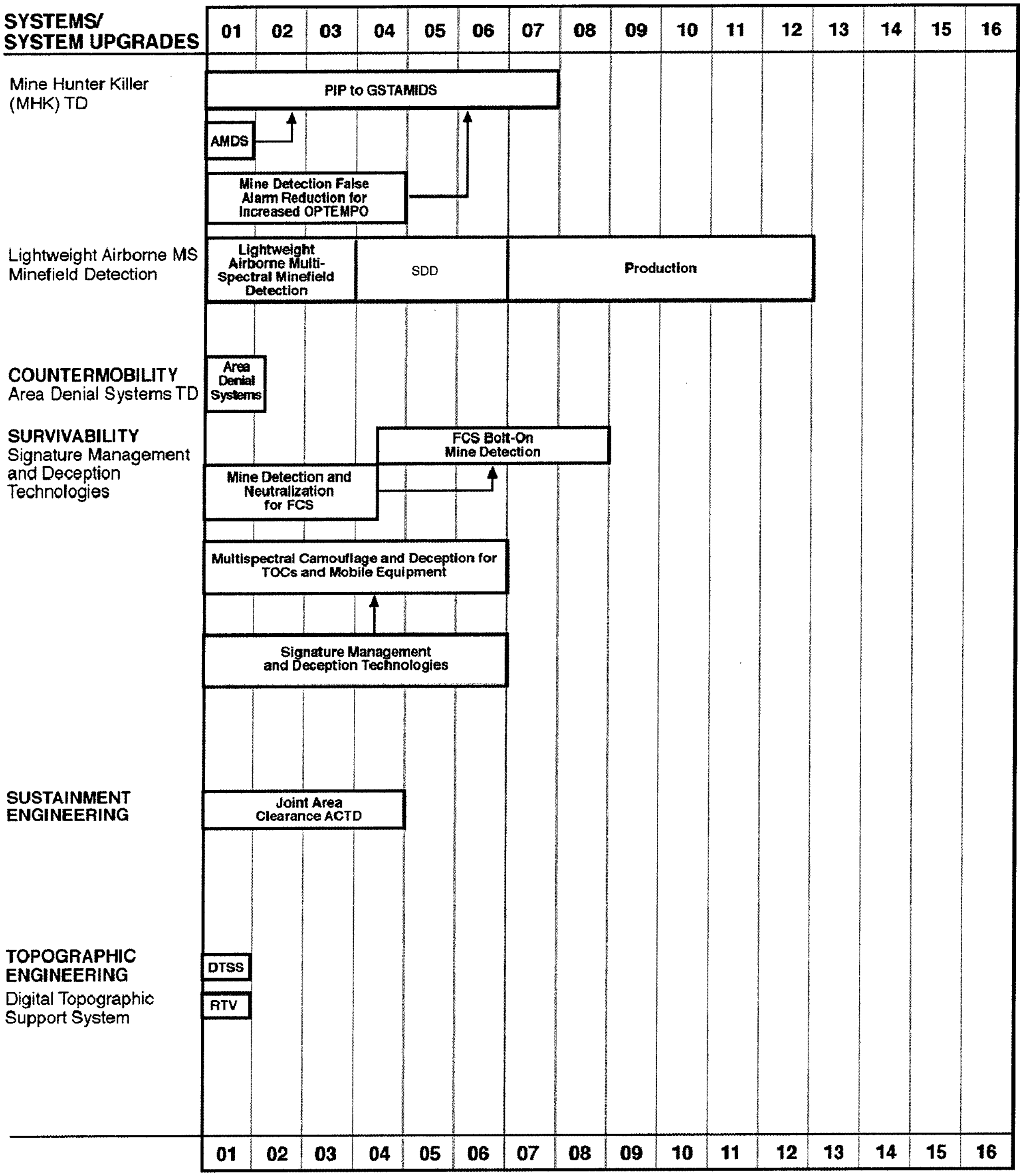


FIGURE III–37. ROADMAP—ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY

M LOGISTICS

The operational construct for the Objective Force poses tremendous challenges to the logistics community. Advanced maneuver and warfighting concepts such as highly decentralized operations, extremely high tempo, and operational reach will depend on similarly radical advances in sustainment capabilities. In fact, it appears that the revolutionary capabilities projected for the Objective Force will not be achieved unless and until there is a corresponding revolution in military logistics and transformation of combat support and combat service support. Moreover, the most important improvements necessary to achieve CS/CSS Transformation are a radical reduction of logistics footprint in the battlespace and reduced cost of logistics without jeopardizing combat capability. Reducing the logistics footprint by designing out the demand for support is essential to providing a strategically deployable force that retains its combat effectiveness on the battlefield. Additionally, the responsiveness of logistical processes must continue to improve commensurate with the introduction of advanced technologies.

The technologies within the Logistics area are focused on (1) initiatives such as onboard diagnostics/prognostics that eliminate the requirement to deploy separate sets of test equipment; (2) rapid chemical and microbial water analysis and onsite water purification to eliminate the procurement, storage, and shipping of large quantities of water; (3) efficient food preparation using state-of-the-art field kitchens that are lighter, smaller, and rapidly deployed; (4) in-theater fuel and oil analysis systems that eliminate the current infrastructure and personnel required to perform this analysis; (5) precision munitions that reduce the number of weapons required to achieve target kills; (6) propulsion systems that are more fuel efficient and advanced lightweight armor that requires less energy to propel it over the ground; (7) ultra-reliable components that have MTBFs that exceed planned employment times; and (8) decision support tools for the total logistics picture.

The Army's technology development and transition strategy for future combat systems incorporates technologies to significantly reduce or eliminate the demand for logistics support. These designs dramatically shift the paradigm from huge consumers of logistics to ultra-reliable, energy-efficient, self-sustaining, self-prognostic, self-healing, self-reporting systems.

This section presents an integrated view of the technologies, research programs, and battlefield capabilities of the future that will contribute significantly to the reduced demand for logistics. It is primarily the combat vehicles' design and the OPTEMPO that dictate the frequency of logistics support. Their developers can design out much of the systems' need for logistics. Examples of current Army R&D programs and systems that make contributions to reducing the logistics demand on the battlefield of the future include, but are not limited to, the Aircraft System Self-Healing (ASSH), Future Combat Systems (FCS), Modular Unmanned Logistics Express (MULE), Rotary-Wing Vehicle (RWV) prognostics, alternative propulsion sources, and the Integration High-Performance Turbine Engine Technology (IHPTET) program.

1 Modernization Strategy

a *Combat Service/Combat Service Support Transformation Challenges*

Proactive logistics is now possible given the current and emerging technologies that allow access to predictive real-time information and comprehensive situational awareness. Similarly, like power and energy, maintenance is a major driver of sustainment requirements. Robotics can also play a major role in reducing the sustainment footprint for maintenance and resupply.

One paradigm shift sought by Army logisticians is the goal of ultrareliability to reduce maintenance and supply requirements—both personnel and materiel.

Three core requirements must be met to achieve the ultrareliability desired under *Revolution in Military Logistics*. First, ultrareliability must be incorporated holistically into systems, their component parts, and their integrated assembly. Second, capabilities for anticipatory maintenance—self-diagnostics, prognostics, programmable sensors, artificial intelligence, and failure warning—are required. Third, combat crews must have the know-how and onboard spares needed to repair most equipment failures using embedded technical instructions and modular replacements (interactive electronic technical manuals).

To *project the force*, the logistics community needs:

- Key information technologies that rapidly and automatically identify and track assets, support enterprise process and decision support systems, and support dynamic replanning.
- Access to and use of theater entry technologies such as battlefield visualization and situational awareness.
- Advanced thermodynamic material for unattended, tamper-proof, climatically controlled "smart" containers.
- Access to and use of theater C^2 technologies.
- Advanced material handling equipment.
- Technologies that contribute to the reduction in lift requirements.

To *sustain the force*, the logistics community needs smart combat systems that have:

- Robotic systems for maintenance and resupply as well as intermodal transfer of assets.
- Ultrareliability built in during manufacture.
- Built-in self-prognostics that reports future failures automatically.
- Self-healing subsystems that provide the capability to delay repairs and continue to prosecute the battle.
- Alternative propulsion systems and fuels.
- "Smart" materials that self-heal and adapt to the demands of the battlefield.
- Biomimetic materials that provide quantum increases in strength and are noncorrosive and nonerosive.
- Sensors and artificial intelligence that enable resupply and repair movements about the battlefield with a high degree of impunity.
- Battlefield situational awareness.
- Nanotechnology applied to battlefield manufacture of supplies as well as the maintenance and repair of combat equipment.
- Autonomous, rapid weapon system resupply and rearm.
- Common vehicle platforms that decrease the number of unique item spare parts.
- Common caliber ammunition with decreased weight and modular packaging.

The integration of these initiatives to fulfill the Army's Vision and the logistics modernization is summarized in Table D–1, Annex D, Volume II.

b *Logistics Annex of the ASTMP*

Annex D, "Logistics," in Volume II contains additional details of initiatives in listed in Table III–13 and expanded logistics modernization issues. The integration of the R&D initiatives required to achieve the Army's vision of reduced logistics footprint and replenishment demand are summarized in Table D–2, Annex D.

TABLE III–13. LOGISTICS DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
Early Entry & Resupply Enhanced Coastal Trafficability & Sea State Mitigation **Logistics Demand Reduction—Resupply** Multirole Armament and Munitions **Logistics Command & Control—Situational Understanding** Logistics Command & Control	**Early Entry & Resupply** Affordable Precision Airdrop Resupply Precision Roll-On/Roll-Off Air Delivery (STO) Modular Unmanned Logistics Express **Logistics Demand Reduction—Resupply** Objective Force Logistics Technology Water Purification Technology (STO) Rapid Analysis of Food & Water for Chemical & Microbial Contaminants (STO) E-Sustainment Combat Rations for Enhanced Warfighter Logistics (STO) **Logistics Command & Control—Situational Understanding** Battlefield Ordnance Awareness (STO)	**Logistics Demand Reduction—System Reliability** Concepts for 21st Century Truck-Based Tactical Vehicles (STO) Aircraft System Self-Healing **Logistics Demand Reduction—Prognostics** Rotary-Wing Vehicle Prognostics Petroleum, Oil, & Lubricants Quality Analyzer & Sensors (STO) **Logistics Demand Reduction—Power and Energy** Advanced Tactical Fuels & Lubricants (STO) High-Energy, Cost-Effective Primary & Rechargeable Batteries (STO) Cogeneration for Field Services (STO) Integrated Power Generation & Management Technologies (STO) Power Conversion Technology for Future Combat Systems (STO)

System/System Upgrade/Advanced Concept	
System Upgrade Aerial Delivery Early Entry Advanced Resupply/Rearm Logistics Demand Reduction—System Reliability Command & Control—Situational Understanding Logistics Demand Reduction—Power and Energy	**Advanced Concept** Advanced Development Airdrop/Aerial Delivery Advanced Resupply/Rearm Modular Unmanned Logistics Express Logistics Demand Reduction—Prognostics Logistics Demand Reduction—Power and Energy Water Purification Technology

2 System Demonstrations

The Logistics technology subareas are Early Entry and Resupply, Logistics Demand Reduction—Resupply, Logistics Command and Control—Situational Understanding, Logistics Demand Reduction—System Reliability, Logistics Demand Reduction—Prognostics, and Logistics Demand Reduction—Power and Energy.

a *Early Entry and Resupply*

The logistics community requires a capability to rapidly deploy and insert Army assets and supplies into restricted terrain during the day or night, in any weather. Logisticians require access to and use of theater early entry and technologies commensurate with the air insertion of the warfighters and the Objective Force. To meet the deployment time constraint, logistics modernization must include initiatives that reduce or eliminate the current intermodal transfer shipment delays. The current early entry and resupply technology programs fall into four categories: air drop, air delivery, over the shore, and robotic.

AFFORDABLE PRECISION AIRDROP RESUPPLY TD (2000–04). Semirigid deployable wing (SDW) technology will be used to demonstrate precision, high-offset delivery of supplies and equipment. *Supports:* PM–SDW, PM–Soldier Support, APM Airdrop.

PRECISION ROLL-ON/ROLL-OFF AIR DELIVERY STO (2000–04). This STO demonstrates and integrates technologies for air delivery of cargo. *Supports:* PM–Precision Roll-On/Roll-Off Air Delivery System in FY03, PM–Affordable Precision Resupply Air Delivery System and Objective System Long-Range Resupply in FY05.

MODULAR UNMANNED LOGISTICS EXPRESS (MULE) TD (2009–11). This program will develop and flight-demonstrate a UAV configuration that supports automated logistics movement of modular payloads up to 10,000 pounds. *Supports:* Aircraft inter- and intratheater capability

ENHANCED COASTAL TRAFFICABILITY AND SEA STATE MITIGATION ATD (1998–02). This ATD minimizes construction time and logistics burdens, and reduces engineering equipment needed to conduct logistics operations over the shore. *Supports:* PM–Force Projection Enabling Systems.

b *Logistics Demand Reduction—Resupply*

The Army needs to reduce the requirement to resupply on the battlefield. Lighter, smaller, and multipurpose munitions will enable logisticians to deliver sufficient/overwhelming lethality to the battlespace. With limited strategic lift, some of the sustenance for deployed forces has to be provided locally. To that end, means to verify potable water sources and food fit for human consumption needs to be developed.

OBJECTIVE FORCE LOGISTICS TECHNOLOGY TD (2006–07). Develop and demonstrate advanced ammunition logistics technologies to reduce the logistics burden, enhance strategic mobility, and provide responsive support. These include Modular Resupply Modules—Ammunition, modular designs, advanced materials, and embedded sensors. *Supports:* PM–AMMOLOG, the RML.

WATER PURIFICATION TECHNOLOGY STO (2001–04). This program will produce a handheld water purifier and a water production system for small units that purifies water from any source (including desalination) or generates water. The purifiers will produce 100 percent of a soldier's daily potable water requirement, reduce the weight of water or water supply equipment that must be transported by 25 percent, and reduce operating costs (price per gallon) by 20 percent. This supports water supply concepts for the future Army to reduce demand on the logistical system by requiring fewer water production, storage, and transportation assets. In addition, the load carried by the soldier should be reduced. This will ensure that water provided on the battlefield does not present a health risk to the soldier. *Supports:* PM–Petroleum and Water.

RAPID ANALYSIS OF FOOD AND WATER FOR CHEMICAL AND MICROBIAL CONTAMINANTS STO (1999–04). This program reduces logistics demand and host nation support. *Supports:* Medical Corps.

E-SUSTAINMENT TD (2004–06). This TD operationally demonstrates wholesale and retail logistics integration. *Supports:* Army's vision to aggressively reduce logistics footprint and replenishment demand.

COMBAT RATIONS FOR ENHANCED WARFIGHTER LOGISTICS STO (2000–03). This STO extends shelf-life, monitoring, and acceptance of rations with improved packaging. By FY03, a logistically focused ration system will be developed that tailors the components to the combat situation and radically improves mobility using advanced processing and packaging technologies that stabilize

ration components, impart appearance of freshness, increase nutritional value, and reduce food waste through enhanced acceptance and a sensor-based ration selection and logistics tracking system. *Supports:* DoD Food Program

MULTIROLE ARMAMENT AND AMMUNITION ATD (2002–05). This program will develop technologies to reduce the munitions logistics burden and increase battlefield survivability for the FCS. It will develop and demonstrate technologies, including a high-efficiency modular ammunition package and an automated upload system that loads this package directly into the FCS autoloader to reduce rearm times by up to 50 percent over the current manual, labor-intensive logistics system. The result will be an integrated, seamless logistics system that increases FCS firepower by decreasing rearm downtime. (See Section III–G, "Weapons," for additional information.) *Supports:* PM–FCS, the RML.

c *Logistics Command and Control—Situational Understanding*

The essentially CONUS-based force of today and the planned Objective Force rely on near-real-time information to ensure that appropriate and timely decisions are made during deployment and sustainment operations. The logistician is an integral part of the warfighter's planning and execution. Because of the dynamic movement and dispersion of friendly combat forces being planned by the warfighters to shape the battlespace, the logistician requires more than the traditional knowledge of asset visibility but also knowledge of the battlespace itself—the terrain, threat disposition, obstacles such as minefield, etc. Demands for current and future logistics support need to be automated and self-reporting.

LOGISTICS COMMAND AND CONTROL (LOG C^2) ATD (1999–03). The Log C^2 ATD will revolutionize tactical decisionmaking for Army logisticians through development, demonstration, and transition of software products that enhance combat service support (CSS) decisionmaking capabilities. The program will enable real-time planning and situation data visualization by interfacing with current and emerging CSS systems. The Log C^2 ATD will provide data to commanders to enhance the planning of future operations and the execution of current operations. These enhancements will cut planning times and allow commanders to use CSS information as an enabler in the 1-hour Force XXI decision cycle. Complete access to automated CSS data will be available down to the unit level. *Supports:* PM–CSSCS, PM–GCSS–A.

BATTLEFIELD ORDNANCE AWARENESS (BOA) STO (1999–02). This STO will result in a near-real-time ordnance reporting system that uses onboard processing with space sensors. It will provide the ability to identify ordnance inventory requirements by ordnance type. *Supports:* PM–Space-Based Infrared System, PM–UAV (Predator and Global Hawk).

d *Logistics Demand Reduction—System Reliability*

"Designing the demand out" of combat systems for logistics support is the only way to achieve the magnitude of reduced logistics footprint being espoused by Army senior leadership. System reliability is a key factor in attaining the required force projection times, reducing the demand for logistics, decreasing the life cycle O&S costs, and meeting the stated requirement to reduce logistics footprint within the battlespace.

CONCEPTS FOR 21ST CENTURY TRUCK-BASED TACTICAL VEHICLES STO (2000–03). This STO will explore virtual prototyping designs of truck-based tactical combat vehicles. *Supports:* PM–Heavy and Tactical Wheeled Vehicles.

AIRCRAFT SYSTEM SELF-HEALING (ASSH) TD (2006–08). This program will demonstrate robust fault detection and identification of critical failures through onboard expert system diagnostics, compensation strategies for damaged aircraft subsystems, and smart flight control component technology. Details are provided in Section III–C, "Aviation." *Supports:* Far-term advanced concepts.

e *Logistics Demand Reduction—Prognostics*

Built-in, real-time, self-reporting prognostics provides a capability to predict faults based on the actual health status of combat equipment. Warfighters will now know if their combat equipment will fail for other than enemy action reasons prior to committing to battle. Onboard prognostics also shifts the paradigm for logistics support from reactive to proactive. The logistician can proactively respond to an impending failure and remove and replace the part prior to failure. This minimizes the vulnerability of the combat vehicle and the combat "downtime" on the battlefield. It also eliminates potential collateral damages that would otherwise require additional logistical support. Prognostics will provide a capability to assess the health status of prepositioned assets in real time. This allows only those parts, tools, and personnel required to affect the repairs to be deployed.

ROTARY-WING VEHICLE (RWV) PROGNOSTICS TD (2008–11). This TD will enable prediction of RWV component and system safe life, thus decreasing maintenance labor hours and substantially increasing aircraft availability for service. *Supports:* Current and future Army aircraft.

PETROLEUM, OIL, AND LUBRICANTS (POL) QUALITY ANALYZER AND SENSORS STO (2000–04). This program will develop and demonstrate devices to diagnose mechanical problems and extend oil and lubricant life. *Supports:* PM–Petroleum and Water.

f *Logistics Demand Reduction—Power and Energy*

Distribution of hydrocarbon-based fuels on the battlefield is the most challenging issue facing logisticians. With no next-generation fuel in sight, the alternatives to reducing the demand for hydrocarbon-based fuels are to reduce the weight of the vehicles, improve aerodynamics, reduce drivetrain friction, and squeeze out the last vestiges of fuel efficiency from internal combustion engines. Electric drives still require massive energy distribution on the battlefield. Long-duration portable power sources must be developed to replace today's batteries.

ADVANCED TACTICAL FUELS AND LUBRICANTS STO (2000–03). This STO will develop enhanced fuels and lubricants that provide future and legacy vehicle systems an average of 3 percent improvement in fuel economy. Other enhancements will reduce scheduled maintenance by allowing systems to operate for longer periods without requiring a change of lubricants. A 50 percent reduction in maintenance is the goal. The program will demonstrate the improvements in fuel economy and longer time between service intervals. *Supports:* PM–Petroleum and Water.

HIGH-ENERGY, COST-EFFECTIVE PRIMARY AND RECHARGEABLE BATTERIES STO (1998–02). By modifying cost-effective commercial technologies, this program will result in advanced high-energy batteries and hybrid power sources for use in training and combat. A 20 percent increase in energy content and proof-of-principle electrochemical capacitors for hybrid, digital-pulse C^4 applications will be demonstrated. High-performance batteries (>300 Wh/kg) and optimized, scaled-up prototype electrochemical capacitors for high-voltage, high-power vehicle hybrid applications

are planned for demonstration by FY01. The goal is to reduce manufacturing costs while maximizing performance and safety. *Supports:* PEO–C^{3}S, SOCOM, PM–TRCS, PM–Soldier, PEO–IEW.

REFORMING DIESEL (COGENERATION) STO (1999–01). Efficiently cogenerating heat and electrical power from one process by integrating generators with burners in mobile food services (kitchens, sanitation, laundries, and space heating) will reduce the logistics footprint by reducing the replenishment demands. Cogenerators will reduce the weight, noise, air pollution, and maintenance associated with standard generators, maximizing efficiency while minimizing cost. *Supports:* PM–Soldier Support, Army Field Feeding Equipment 2000.

INTEGRATED POWER GENERATION AND MANAGEMENT TECHNOLOGIES STO (2000–02). The intent of this program is to plan, organize, and control energy-efficient technologies and techniques across all elements of Army power (sources, storage, distribution, and consumption). The first step is to demonstrate smart hybrid battery/electrochemical capacitors using components from leveraged programs. Next, an assessment of kinetic energy component technologies will be conducted. A demonstration of optimized electromechanical technology on a 5-kW testbed is also planned. Ultimately, this program will design and develop a 500-W thermophotovoltaic power system for power-on-the-move. *Supports:* PM–Land Warrior, PM–Soldier, PM–MEP.

POWER CONVERSION TECHNOLOGY FOR FUTURE COMBAT SYSTEMS STO (2001–04). Power conversion is an enabling technology for hybrid/electric drive capability, which greatly improves fuel efficiency, thereby reduces the logistics footprint of the future Objective Force, and reduces converter size by 60–75 percent and weight by 50 percent. *Supports:* FCS, the RML.

3 ROADMAP

Figure III–38 is a roadmap of the logistics S&T programs.

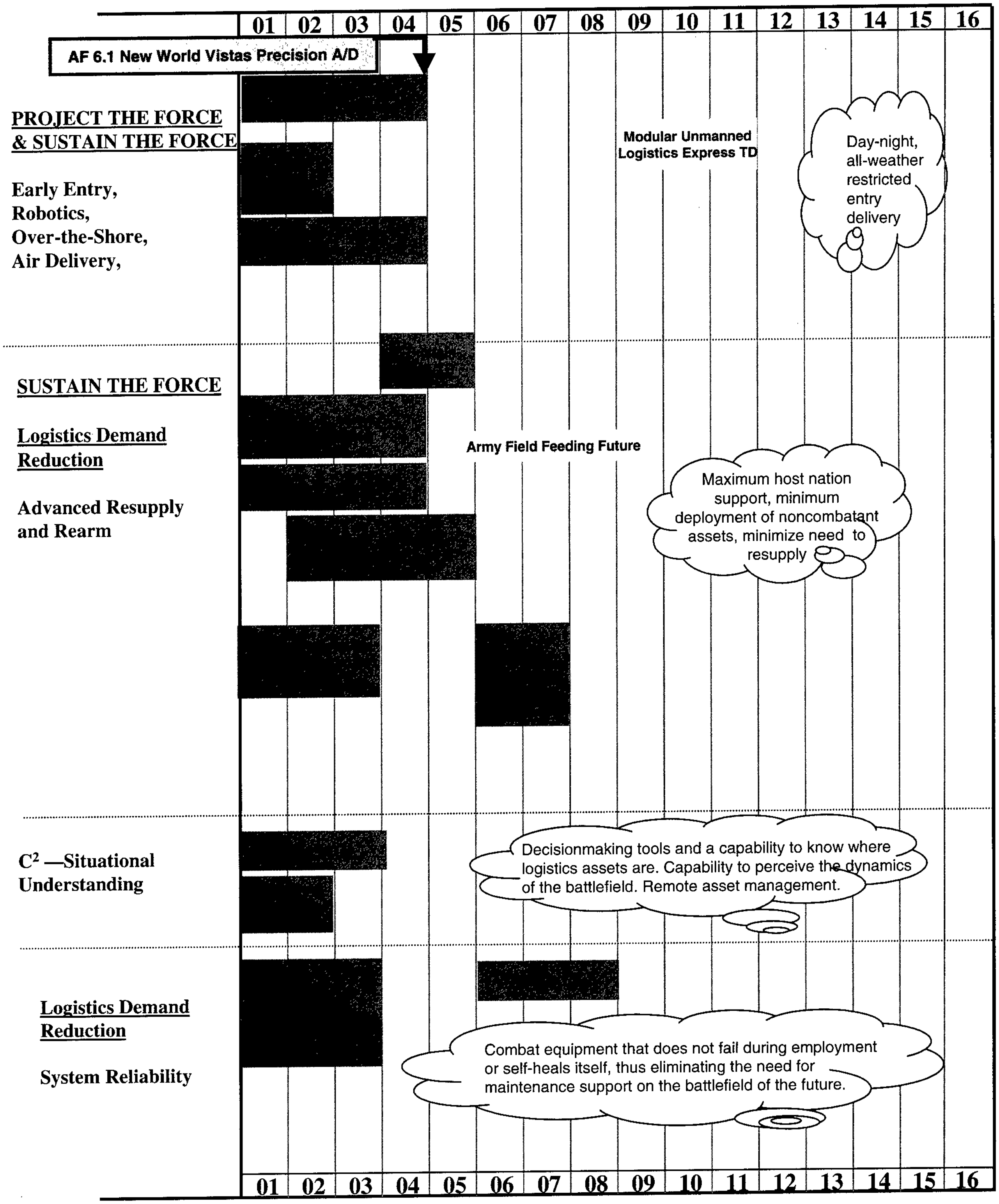


FIGURE III–38. ROADMAP—LOGISTICS

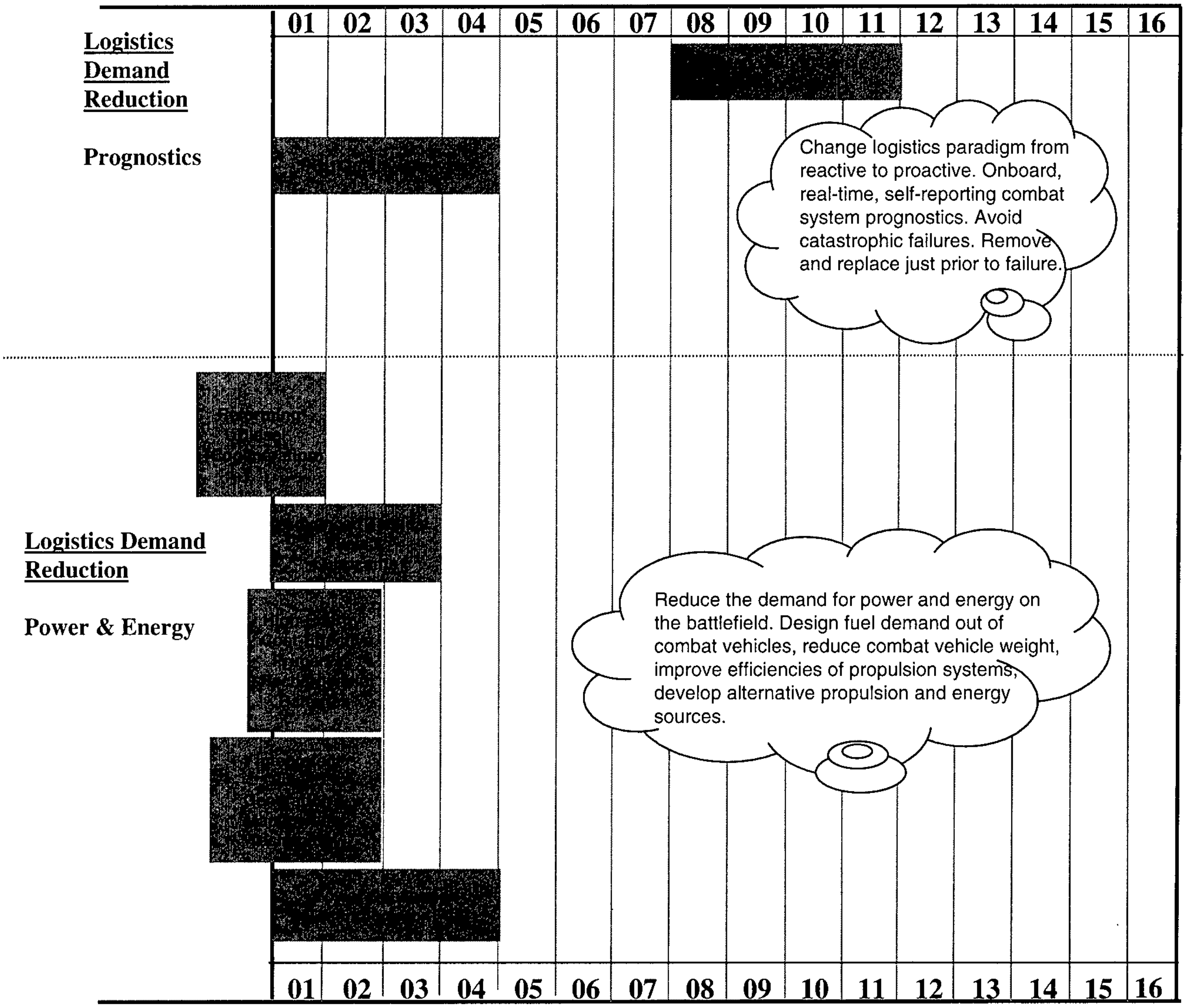


FIGURE III–38. ROADMAP—LOGISTICS (CONT'D)

N PERSONNEL PERFORMANCE

The key goal of the Army's Personnel Performance technology development program is the development and transition of technology that will enhance Objective Force soldier performance in a variety of both current and future missions. The Army's Personnel Performance program is part of the DoD defense technology area for Human Systems and Information Systems Technology. The national security strategy stresses a wide spectrum of missions, including humanitarian assistance and disaster relief, peacekeeping and peacemaking, countering threats from regional powers, coping with regional instabilities, fighting major theater wars, and preparing to defend against nuclear threats. A force projection Army must be ready to execute diverse missions at any time, anywhere in the world. These demands challenge personnel just as they challenge the equipment and materiel that are the conventional focus of technology.

Army personnel performance technology developments can meet these challenges through the application of behavioral science and emerging technologies to enhance soldier recruiting techniques, individual land warfare training, battle command training, unit training, and simulation-based training. These advances will be used to increase mission readiness for both active and reserve forces and improve the training for new missions. Commanders will be able to provide tough, realistic, battle-focused training to prepare soldiers and leaders to dominate in all aspects of their missions.

1 Modernization Strategy

America's 21st century Army will increase training in a digitized battlefield achieved through a synergy of live, virtual, and constructive simulations. Training strategies, organizational redesign, battle command training, and personnel issues will evolve into an interactive cycle of experimentation and assessment with virtual and actual units and in support of the battle laboratories.

Current and emerging system concepts are enabled through the following training methodologies and systems:

- Distributed interactive simulation (DIS)
- Advanced distributed learning (ADL)
- Combined arms tactical trainer (CATT)
- Nonsystem training devices.

The upgrades to these programs—together with prototype support packages, training aids, devices, simulators, and simulations—will provide the means for meeting the Army's training modernization objectives.

Future training technology initiatives will have high potential payoff (i.e., reduced training time and resource consumption) for both the active and reserve components. Initiatives must offer solutions that offset a decreasing force structure and ensure the means for providing realistic, dynamic training at both the home station and the combat training centers (CTCs). The CTCs must be augmented by training aids and devices to provide a cost-effective training environment, using warfighting equipment in conjunction with simulated environments. A DIS capability combined with other ADL methods will permit the development of synthetic battlefields for training that complement field training exercises at the CTCs, as well as bring training to the sol-

dier wherever and whenever needed. This capability will be of particular value to the reserve component, with its limited number of training days.

Table III–14 summarizes the personnel performance system upgrades and advanced concepts.

TABLE III–14. PERSONNEL PERFORMANCE DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
[None scheduled for FY01]	**Unit Collective Training** Training Strategies for the Objective Force (STO) **Simulation-Enhanced Training** Combined Arms Tactical Trainer Aircrew Coordination Training Reserve Component Training Strategies	**Individual/Land Warfare Training** Strategies for Training on Demand **Technology Programs for Improving Personnel Performance and Leadership Development** Special Forces Personnel Development Command Climate Assessment Methodology

System/System Upgrade/Advanced Concept	
System Upgrade Combined Arms Tactical Training Strategy Nonsystem Training Devices Combined Arms Tactical Trainer	**Advanced Concept** Innovative Distributed & Simulation-Based Training Strategies Advanced Personnel Assessment and Development Technologies

The combined arms training strategy (CATS) is the Army's architecture for training and educating its people and units. CATS provides the conceptual framework for establishing training policy and resource requirements. The objective of the CATS architecture is to provide doctrine–based strategies for training warfighting tasks and skills in institutions, in units, and through self-development. CATS is the framework that will be used to design and execute effective unit training programs in a resource-constrained environment. Supporting technology developments that will lead to the advanced concepts are described below.

2 System Demonstrations

The Personnel Performance technology subareas are Unit Collective Training, Simulation-Enhanced Training, Individual/Land Warfare Training, and Technology Programs for Improving Personnel Performance and Leadership Development.

a *Unit Collective Training*

The purpose of this work is to develop technologies for improving the training of units to prepare for operations envisioned for the Objective Force. Technologies will include methods of improving skill retention and training transfer with the move from conventional to digital systems, and training and evaluation methods (in support of the Mounted Battlespace Battle Laboratory) that will prepare operators, commanders, and staffs to take maximum advantage of the evolving digital C^3 systems of the FCS. The unit collective training work includes the effort on future training strategies. That effort has so far produced designs of prototype training methods and associated performance enhancement instruments, and conducted front-end analyses for simulation-based training focusing on the Close Combat Tactical Trainer (CCTT) with an M1A2 battalion task force. This work will produce prototype training and performance evaluation techniques to support digital integration capabilities for the Objective Force, the Army's CATS, and Innovative Simulation-Based Training.

TRAINING STRATEGIES FOR THE OBJECTIVE FORCE STO (2001). This program is expected to produce prototype platoon and company team training support packages for digital operations as delivered by the CCTT.

b *Simulation-Enhanced Training*

Today's Army must be capable of producing swift, decisive, low-casualty victories across the spectrum of conflict anywhere in the world. Simulated environments can be tailored to provide realistic training for these missions, and these simulators must be used to maximize training effectiveness while keeping costs low. The technology development in this area includes new simulator-based training strategies for reserve component training. By its completion in FY01, the reserve component training work will produce validated strategies for using small arms simulators to train and evaluate rifle marksmanship performance and validated techniques for determining the minimum number and type of live-fire engagements needed for accurate assessment of armor crew-served weapon qualification. Aviator training is costly and dangerous. Work will focus on refinement of the enhanced Aircrew Coordination Training Program and establishment of web-based reporting and repository systems for Army crew coordination.

This work will involve development, expansion, and assessment of prototype training packages based on structured simulations developed previously. *Supports:* DIS, innovative simulation-based training, PM–CATT.

c *Individual/Land Warfare Training*

The purpose of this work is to develop innovative and cost-effective methods and programs that deliver training on demand whenever and wherever needed to improve a soldier's ability to employ complex, high-technology weapons and equipment and perform effectively in various operational environments. This work will compare the training effectiveness of up-front versus just-in-time training methods. Developments in this area focus on improving the training of soldiers and commanders on tasks requiring information-age digital skills. Individual training in the Army is shifting from a system that is classroom based to one that will deliver instruction wherever and whenever needed (i.e., on demand). By FY02, this effort will provide the Army with guidelines for designing training in procedural and adaptive thinking skills, thereby enabling soldiers to perform the variety of new missions they may be required to execute. This training will be delivered on demand in the workplace or at home. *Supports:* ADL.

d *Technology Programs for Improving Personnel Performance and Leadership Development*

The objective of this effort is to maintain and enhance the quality of the Army by providing effective recruiting, selection, assignment, and attrition-reducing strategies; improved personnel support systems; methods to determine the unique job requirements for 21st century non-commissioned officers; an array of instructional techniques to foster conceptual thinking by Army leaders; and feedback strategies needed to foster a positive command climate. This work will produce methods to improve Special Forces team performance as a model for the Army of the future, and will develop techniques for assessing the Army's current command climate and trends over time. By FY02, it will provide the Army with methods and strategies that Special Forces leaders can use to diagnose problems, design solutions, and implement and evaluate individual, team, and organizational-level interventions. It will also conduct annual assessments of the Army command climate and identify new issues of concern to soldiers. *Supports:* Advanced personnel assessment and development technologies.

3 Roadmap

The roadmap in Figure III–39 details the Army's current plans to support future training initiatives. Limited advanced development funding for training system upgrades is available in the outyears.

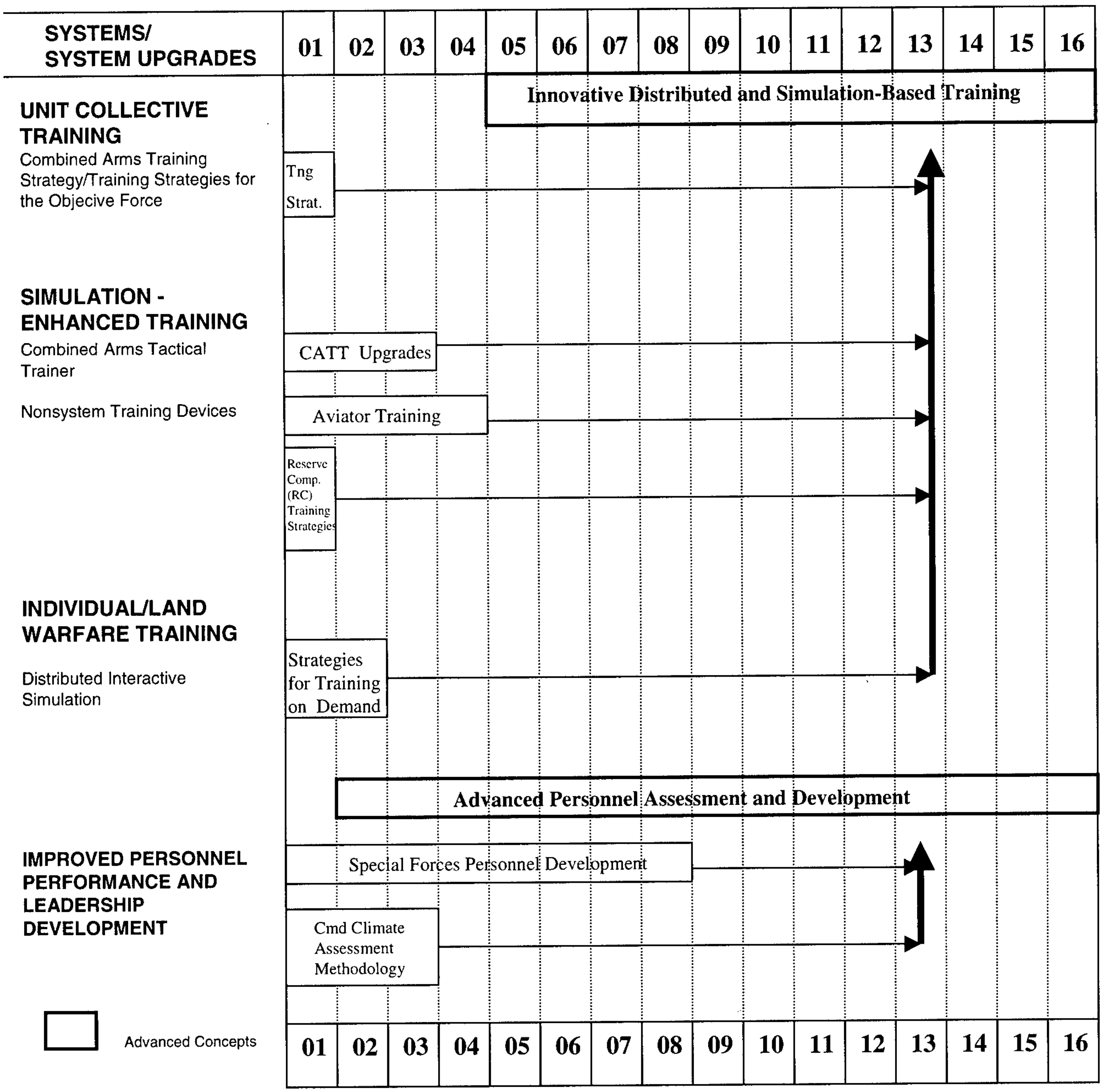


FIGURE III–39. ROADMAP—PERSONNEL PERFORMANCE

O SPACE

The Army Vision states the need to achieve strategic dominance across the entire spectrum of operations. The spectrum of likely operations requires land forces operating in joint, combined, and multinational formations for a variety of missions extending from humanitarian assistance and disaster relief to peacekeeping and peacemaking in major theater wars, including conflicts involving the potential use of weapons of mass destruction. Access to space assets is critical to the Army's ability to accomplish its missions. Space access requires freedom of operations within the space medium, and, if required, denying space access to others. U.S. Army TRADOC and U.S. Army Space and Missile Defense Command (SMDC) have agreed to designate SMDC as the proponent for space activities and established the Space and Missile Defense Battle Laboratory (SMDBL) to lead these efforts. SMDC combat developers will interact with TRADOC schools and other battle laboratories to develop requirements for the capabilities needed to support land combat operations today and into the future.

Control of space is the ability to ensure access to space and freedom of operations within the space medium, and the ability to deny others the use of space if required. The Space Control System will be a suite of technologies acting in an integrated architecture. Achieving and maintaining control of space will influence all national and military objectives. Space force enhancement capabilities are critical enablers to achieving information dominance and to ensuring full-spectrum dominance across all levels of conflict. The Army must be able to prosecute information-intensive operations in a multidimensional battlespace more deliberately than ever before. The Army must dominate the EM spectrum to ensure uninterrupted data flow between joint and friendly multinational forces around the world—and influence that same data flow between adversarial forces. The S&T challenge in space is to determine how to exploit, leverage, and horizontally integrate the military, civil, and commercial space technologies and capabilities into the Legacy Force, the Interim Force, and the Objective Force. The program for space S&T leverages technology developments from other services, as well as government agencies, industry, and academia. This is also a systems approach to the integration of space and space-related technologies, otherwise known as space control.

The Army requires space products that will allow land force dominance through situational awareness and space-based capabilities that are adaptable and deployable to meet the Army's force projection requirements.

Army S&T focuses on relevant space capabilities and technologies to support the Army modernization strategy and investment plans. This ensures that essential space technologies are developed and integrated into the current and programmed force to maintain the required overmatch capabilities against potential adversaries. Additionally, guidance is provided for supporting the potential force with leap-ahead space technologies and capabilities required for full-spectrum dominance.

1 Modernization Strategy

The modernization of Army space systems must be focused on (1) enhancing current satellite systems through more effective use of equipment and (2) influencing new satellite designs to provide significant value added and improved capability for the warfighter. The proliferation of space products obtainable throughout the world—together with smart weapon technologies—poses a threat to U.S. forces. As potential adversaries continue to acquire modern technology to enhance their capabilities, it is clear that the Army's access to and exploitation of space capabili-

ties must be upgraded through continuous modernization. Inserting or embedding highly advanced space technologies into Army systems is essential to maintain combat overmatch. Controlling space tomorrow means ensuring that U.S. long-term needs will be met by efforts that are planned and programmed today.

To facilitate effective modernization, it is important that the Army plan on incorporating space and space-based assets into solutions to Army warfighter requirements. The Army approach to space S&T follows:

- Use Army laboratories, schools, and battle laboratories to evaluate and understand future operational capabilities, advanced operational concepts, and potential technological advances.
- Develop technical requirements, and influence the space system designs of other services, government (national, civil, and DoD), and commercial space systems to support Army patterns of operations.
- Integrate space technologies and capabilities into Army battlefield operating systems to sustain current overmatch capabilities.
- Exploit and leverage existing space technologies, capabilities, and systems—drawing on government (national, civil, and DoD), commercial, and foreign resources—to achieve leap-ahead capabilities necessary for full-spectrum dominance.

The focus for technology development is to exploit space and provide relevant space capabilities to the warfighter while improving information needed for the warfighting CINC. Many Army S&T institutions can provide technology options to the warfighter. They have ongoing programs in sensor development, algorithm development, and processing to aid in ATR, battlefield visualization, and TMD applications. The keys to success are the proof-of-concept or advanced technology development demonstrations that can provide applications for use in an effective space architecture.

The Army's space force enhancement control and space-related S&T programs are focused on providing capabilities to the warfighter through:

- Sensors that are multifunctional and that leverage commercial technology.
- Processors that decrease the decision cycle, provide processing in theater with rapid access to stored data, provide automatic or aided target recognition, and provide advanced decision aids that include AI attributes.
- Assured access to medium- and high-data-rate satellite communications—commercial and national.
- Multiband land-based terminals.
- Integrated, seamless information exchange across strategic and tactical domains, including dynamic bandwidth allocation.
- Space control efforts to deny enemy information on friendly capabilities while protecting our space assets.
- The capability to obtain target signatures of interest during day or night operations capable of penetrating weather and concealment.
- Accurate measurement and prediction of environmental conditions over areas of interest.
- Integration of space capabilities into modeling and simulation.
- The capability to provide theater missile attack warning and cueing to friendly forces and allies.
- The capability to provide real-time, survey-quality pointing accuracy for directional systems, including weapon systems.

- Real-time, direct downlinking of raw and onboard processed data from space-based assets to tactically deployed units that are equipped to process and exploit data.
- Position and navigation devices to navigate accurately across highly uniform terrain areas (jungle and desert).
- The capability to provide warning of hostile and friendly fires from artillery and tactical missiles in near-real time to effect counterfire or evasion.
- The capability to provide warning to TMD and air defense systems of ducting and false target ranges caused by thermal layering and other atmospheric and stratospheric phenomena.
- Direct tasking of national systems.
- Improvement and integration of more advanced, automated, integrated precise elevation and geographic positioning generation capabilities from national systems at the tactical level for immediate targeting support.

These capabilities support several TRADOC battle laboratory operational capability requirements and Army modernization objectives. They include applied research and advanced technology development that add value to battlefield operating systems.

In the near term, part of the space modernization strategy is to leverage, buy, and exploit commercial and military systems, terminals, and receivers for application on current satellite systems. This strategy includes:

- Defining requirements and focusing technologies to influence future applications of planned systems.
- Leveraging technologies and capabilities for information dominance and for the design and development of future satellite systems to satisfy Army requirements.
- Integrate commercial space capabilities to augment Army space systems.

Table III–15 summarizes demonstrations found in the Space roadmap.

TABLE III–15. SPACE DEMONSTRATION AND SYSTEM SUMMARY

Advanced Technology Demonstration	Technology Demonstration	
There are no ATDs for Space. (Two ATDs in Section III–D, "C^4," deal with Space.)	**Intelligence, Surveillance, & Reconnaissance & Mapping** Eagle Vision II (Direct Downlink & Direct Tasking of Commercial Imagery Satellites) Overhead Passive Sensor Technology for Battlefield Characterization (STO) Battlefield Ordnance Awareness (STO)	**Space Control** Space Surveillance (STO) Aerospace Control Battle Management Command, Control, Communications, Computers, and Intelligence

System/System Upgrade/Advanced Concept	
System Eagle Vision II Joint Tactical Ground Station **System Upgrade** Single-Channel Antijam Man-Portable Terminals Communications	Exploitation of Commercial/Civil Imagery Theater Missile Defense Weapons **Advanced Concept** Communications Transport Advanced Sensor Collection & Processing

2 System Demonstrations

The Space technology subareas are C^4I, ISR and Mapping, and Space Control.

a *Command, Control, Communications, Computers, and Intelligence*

The speed of communications and the pace of events, as well as the need to operate inside the enemy's decision cycle, require the ability to rapidly monitor and respond to events worldwide. Space C^4I has the largest battlespace—a truly global arena. Space C^4I assets must interface with and fuse data from a multitude of dissimilar sensor (IR, RF, optical, acoustical) and intelligence platforms using different message protocols, data types (track files, raw data), and hardware interfaces. Large numbers of air and space objects must be considered before space assets can be allocated to the requisite mission. Other factors that must be taken into account include multiple windows of opportunity for implementing a solution and alternative space assets (with dissimilar technical characteristics) for fulfilling the mission. Space C^4I also requires near-real-time coordination with other national and commercial space assets.

Advances in information systems have made more information available to warfighters during real-time operations. It is essential to provide information in a manner that will augment the battle commander's decisionmaking capability without information overload. A well-designed, human-engineered system interface is paramount for minimizing operator decision response times and error rates, while maximizing interaction efficiency. Optimizing solutions for space asset mission tasking requires synchronized hyper-real-time processing (hyperspeed evaluation of alternatives) and sophisticated decisionmaking algorithms.

b *Intelligence, Surveillance, and Reconnaissance and Mapping*

Space ISR takes advantage of the highest ground. ISR sensors can provide the commander regular information on denied areas via multiple phenomenology (RF, EO, IR, and nuclear). Space provides an effective approach to wide area surveillance to support various mission areas on the battlefield. ISR assets can generate far more data than can possibly be handled and processed by humans. Near-real-time algorithms are needed to make the data information usable for the warfighter. This includes terrain feature extraction for mapping and automated event and target detection and typing. Tactical use of space ISR in near real time by the lower echelons requires a departure from the conventional separation of fire control, intelligence, and situational awareness. These space assets require in-theater exploitation for effective and cooperative use of organic ISR.

EAGLE VISION II (EV–II) TD (DIRECT DOWNLINK (DDL) AND DIRECT TASKING OF COMMERCIAL IMAGERY SATELLITES) (1998–02). EV–II will provide a direct downlink of unclassified, remotely sensed imagery from commercial satellites to the supported commander. Downlinked data will be processed and provided to users in standard image formats for command and control, mission rehearsal, intelligence, and geographic information systems. EV–II will consist of an air- and sea-transportable 30-foot "expando" van containing a data acquisition segment, a data integration segment, and a 5-meter X-band antenna. It will provide near-real-time unclassified commercial imagery from panchromatic multispectral and radar imagery. The demonstration will pass imagery to a digital terrain support system for terrain analysis and data generation at digital terrain elevation levels 1 and 2. It will also pass imagery from the RISTA systems (e.g., the modernized imagery exploitation system) for intelligence exploitation.

OVERHEAD SENSOR TECHNOLOGY FOR BATTLEFIELD CHARACTERIZATION STO (1997–03). This program will demonstrate several technologies to be used in the collection of multispectral and hyperspectral imagery for the exploitation of remote Earth sensing imagery. It has applications in the areas of ISR as well as terrain analysis. The collection sensors will be used to develop the database required to identify spectral signatures for future exploitation. The prototype sensor will demonstrate Army tactical utility in ground and flight tests. Phenomenology between spectral and polarization will be investigated for detection and identification of tactical targets. These sensors will assist in the development of Army requirements for the next generation of remote Earth sensors. The sensor technology will eventually be transitioned to Army programs for sensor packages, UAVs, and space systems.

BATTLEFIELD ORDNANCE AWARENESS (BOA) STO (1996–02). The BOA program will demonstrate the capability to report both enemy and friendly battlefield ordnance events—including ballistic missile and cruise missile launches—in near real time using space or airborne passive IR sensors with onboard processing. Information displayed on tactical C^4ISR injection systems will enable the theater commander to view the development of the battlefield from a revolutionary new perspective. BOA addresses the need to target ordnance delivery for counterfire purposes—a major battlefield deficiency—as well as the deep-attack mission needs. It will identify the ordnance by type and provide this information for counterfire opportunities, battle damage assessment, deep operations, conflict monitoring, and suppression of air defense systems. Advanced computational processing technologies will be integrated with state-of-the-art passive nonimaging IR sensor technologies to demonstrate a time-critical capability to the tactical commander.

c *Space Control*

Space control provides U.S. forces the ability to gain access to and operate in space and, if required, to deny an adversary the use of space. Development of the space control functional technology area requires identification and description of the necessary tasks and functional integration and testing of an space control architecture. The space control systems concept rests on four pillars:

- *Protection* of critical space systems from hostile actions. Protection consists of passive and active defensive measures to ensure that U.S. and friendly space systems perform as intended.
- *Prevention* of unauthorized access to, and exploitation of, U.S. and allied space systems. Prevention includes measures to preclude an adversary's ability to use U.S. or third-party space systems and services for purposes hostile to the United States.
- *Surveillance* of space to achieve and maintain situational understanding. Surveillance incorporates measures to detect, identify, and track objects and to monitor, assess, verify, and categorize events in space.
- *Negation* of hostile space systems that place U.S. and allied interests at risk. Negation involves measures to deceive, deny, disrupt, degrade, or destroy space systems and services.

SPACE SURVEILLANCE STO (2000–04). The purpose of the space control surveillance plan is to provide a system concept for detection and assessment of hostile or neutral space-based ISR operations in theater. This STO will develop and demonstrate a transportable battlefield-area-of-operations capability for determining the status and operation of threat systems. It will provide the foundation for the space control function technology area through the gathering of information for intelligence analysis. Current technologies such as battle management C^4I, automation, and pattern recognition will contribute to the operational capability for space control surveillance. The use of deployable radars in conjunction with automated data processing will build on the

foundation of existing intelligence capabilities and thereby extend tactical awareness into space on a global perspective. This, in turn, will provide protection through information and analysis for the ground-based theater personnel. Ultimately, it will enable the in-theater commander to (1) increase force protection and situational awareness via detection and alerting, (2) provide "compliance verification" to decisionmakers, (3) integrate and expand the space surveillance capability into existing C^2 networks as other capabilities develop, and (4) provide the information necessary for alternative actions or decisions. The goals of the space surveillance TD are to develop the phenomenology and document and complete the conceptual design (FY00), complete development of the threat database and assessment algorithms (FY01), demonstrate automated near-real-time threat configuration assessment (FY02), demonstrate an integrated laboratory capability (end of FY03), and demonstrate a system-integrated field test (FY04).

AEROSPACE CONTROL TD (2002–05). This program addresses part of the overall space control concept of ensuring access to and freedom of operations within space by giving the theater commander and warfighter a mobile tactical ability to meet threats from high-altitude, long-endurance UAV and imaging threats. This technical demonstration will draw on software R&D efforts currently underway for acquisition and tracking algorithms. To demonstrate the aerospace control mission, existing surveillance and automation technology will be used.

BATTLE MANAGEMENT COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, AND INTELLIGENCE (BMC^4I) TD (2002–05). BMC^4I incorporates emerging and existing communications technologies in a combined and applied format that meets space control requirements. The program will provide automated capabilities to plan, coordinate, deconflict, execute, and assess damage to space objects. BMC^4I provides capability to link ground to space surveillance and satellite operational status to space control negation capabilities.

3 Roadmap

A number of projects are ongoing for the application and development of technologies to exploit space to meet Army requirements. The roadmap for space exploitation technology developments is shown in Figure III–40.

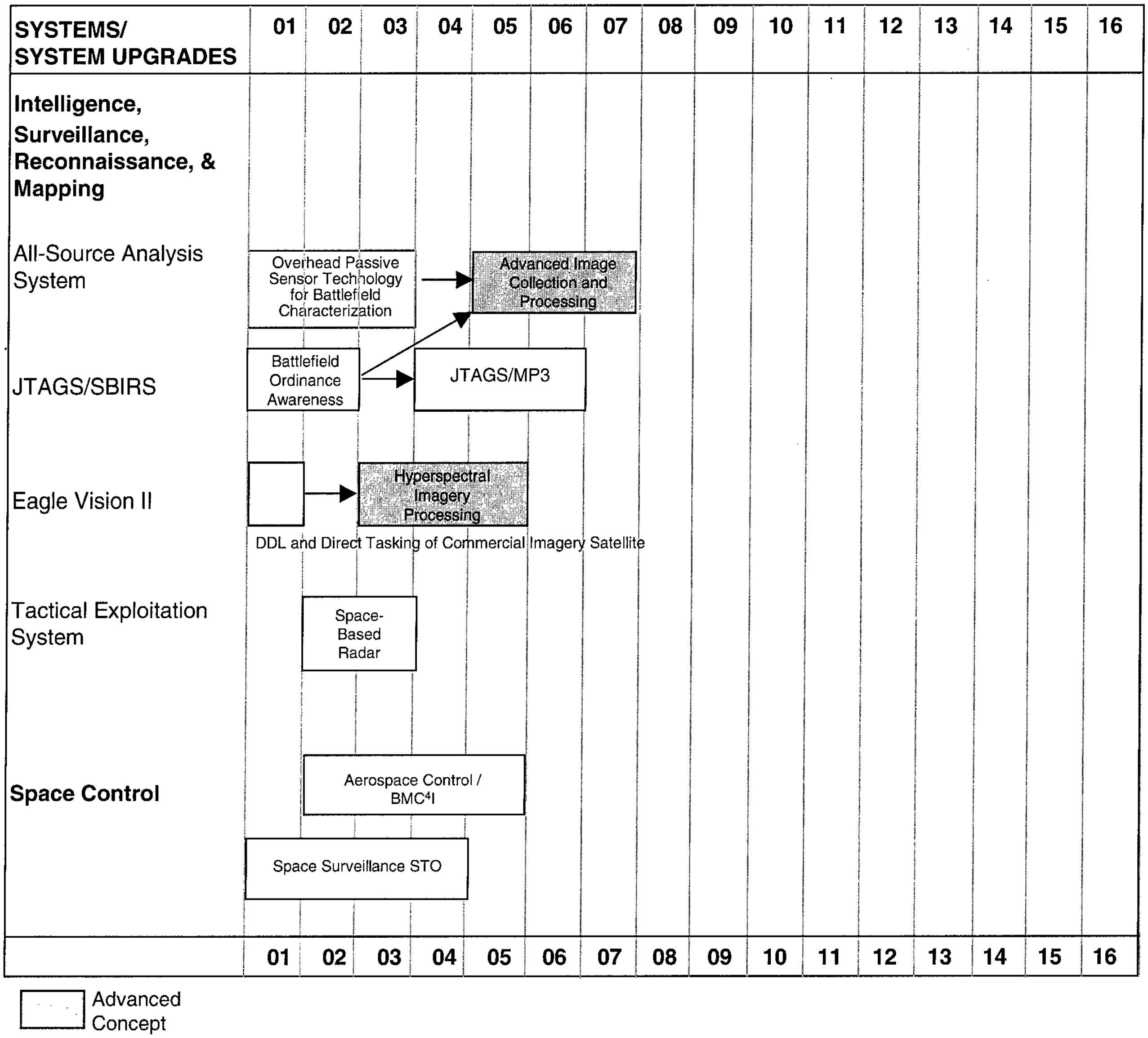


FIGURE III–40. ROADMAP—SPACE

CHAPTER

IV APPLIED RESEARCH (TECHNOLOGY DEVELOPMENT)

CONTENTS

A INTRODUCTION IV–1

B STRATEGY IV–4

C AVIATION IV–5
1 Aeromechanics IV–6
2 Flight Control IV–7
3 Structures IV–9
4 Subsystems IV–9
5 Rotorcraft Drive IV–10
6 Propulsion IV–12

D COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS IV–16
1 Decisionmaking IV–16
2 Seamless Communications IV–18

E ELECTRONIC WARFARE IV–24
1 Electronic Attack/Area Protect IV–24
2 Electronic Support IV–26

F GROUND COMBAT AND TACTICAL SYSTEMS IV–28
1 Systems Integration IV–29
2 Vehicle Structures IV–30
3 Integrated Survivability IV–30
4 Mobility IV–32
5 Vehicle Electronics IV–33
6 Robotics IV–33

G WEAPONS IV–36
1 Guidance and Control IV–37
2 Guns—Conventional and Electric IV–38
3 Missiles IV–39
4 Ordnance IV–39
5 Weapon Lethality/Vulnerability IV–40
6 Radio Frequency Directed-Energy Weapons IV–41
7 Air and Missile Defense IV–42

H SOLDIER AND PERSONNEL TECHNOLOGIES IV–45
1 Information Display and Performance Enhancement IV–46
2 Design Integration and Supportability IV–47
3 Warrior Protection and Sustainment IV–48
4 Personnel Performance and Training IV–50

I BIOMEDICAL IV–55

1 **Infectious Diseases of Military Importance** **IV–57**
2 **Medical Chemical and Biological Defense** **IV–59**
3 **Military Operational Medicine** **IV–60**
4 **Combat Casualty Care** **IV–61**

J CHEMICAL/BIOLOGICAL DEFENSE IV–64

1 **Contamination Avoidance** **IV–65**
2 **Protection** **IV–67**
3 **Decontamination** **IV–68**
4 **Modeling and Simulation** **IV–69**
5 **Smoke and Obscurants** **IV–71**

K ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY IV–74

1 **Civil Engineering** **IV–74**
2 **Environmental Quality** **IV–76**
3 **Mobility and Countermobility** **IV–77**

L LOGISTICS IV–81

1 **Early Entry and Resupply** **IV–82**
2 **Logistics Demand Reduction—Resupply** **IV–83**
3 **Logistics Command and Control—Situational Understanding** **IV–83**
4 **Logistics Demand Reduction—System Reliability** **IV–84**
5 **Logistics Demand Reduction—Prognostics** **IV–84**
6 **Logistics Demand Reduction—Power and Energy** **IV–85**

M MATERIALS, MATERIAL PROCESSES, AND STRUCTURES IV–88

1 **Materials** **IV–89**
2 **Processes** **IV–91**
3 **Structures** **IV–92**

N SENSORS AND ELECTRONICS IV–95

1 **Sensors** **IV–96**
 a Radar Sensors IV–96
 b Electro-Optic Sensors IV–97
 c Acoustic, Magnetic, and Seismic Sensors IV–98
 d Automatic Target Recognition IV–98
2 **Electronics** **IV–99**
 a Millimeter-Wave Components IV–100
 b Smart High-Resolution Displays IV–100
 c Photonics IV–101
 d Solid-State Lasers IV–102
 e Focal Plane Arrays IV–103
 f Microelectronics IV–104
 g Electronics Materials IV–104
 h Integrated Platform Electronics IV–105

O BATTLESPACE ENVIRONMENT IV–108

1 **Terrestrial Environment** **IV–109**

a Signature Physics and Fusion IV–110

b Topography IV–111

2 **Lower Atmosphere Environment** **IV–112**

a Current Battlespace Weather IV–112

b Predicted Battlespace Weather IV–114

c Decision Aids IV–117

P BIOTECHNOLOGY IV–121

1 **Molecular Recognition** **IV–121**

2 **Low-Observables Materials** **IV–122**

3 **Biosensors** **IV–122**

4 **Catalytic Enzymes** **IV–123**

5 **Molecular Toxicology** **IV–123**

6 **Bioprocess Engineering** **IV–124**

7 **Bio-Derived Electronic and Photonic Materials** **IV–124**

8 **Bio-Derived Nanoceramics** **IV–125**

9 **Biofouling and Biocorrosion** **IV–125**

10 **Biopreservation of Food Rations** **IV–126**

List of Figures

IV–1 Aeromechanics Technology IV–6
IV–2 Flight Control Technology IV–7
IV–3 Rotary-Wing Structures Technology IV–9
IV–4 Rotorcraft Enhanced Survivability Technologies IV–11
IV–5 Rotorcraft Drive Technology IV–11
IV–6 Integrated High-Performance Turbine Engine Technology Initiative IV–12
IV–7 Organization of the Rotorcraft Center of Excellence Concept and the National Rotorcraft Technology Center IV–14
IV–8 Collaboration Technology for the Warfighter IV–17
IV–9 Intelligent Agents Visualization IV–18
IV–10 Free-Space Optical Communications System IV–20
IV–11 Physics-Based Methodology to Assess FCS Lethality/Vulnerability IV–41
IV–12 Warrior Protection and Sustainment Areas IV–49
IV–13 Portable Handheld UV LIDAR IV–65
IV–14 Pyrolysis Gas Chromatography Ion Mobility Spectrometer IV–65
IV–15 TSA/PSA Regenerative Filter IV–67
IV–16 Enzyme Foam Decontamination IV–69
IV–17 CB M&S Simulation Suite To Support Technology and System Development IV–70
IV–18 Obscurant Protection IV–72
IV–19 Flash X-Ray of a Bullet Striking a Composite Armor Plate IV–90
IV–20 Topography Science and Technology IV–109
IV–21 Measurements in the Planetary Boundary Layer, Along With Weather Parameters IV–113
IV–22 Lower Atmospheric Environment—Predicted Battlespace Weather IV–116
IV–23 Lower Atmosphere Environment—Weather Decision Aids IV–118

List of Tables

IV–1 Mission Area and Technology Thrust Area Linkages to Objective Force Technology Areas IV–1
IV–2 Mission Area Linkages to DTAP Technology Areas IV–3
IV–3 Technology Objectives for Aviation IV–14
IV–4 Technology Objectives for C^4 ..... IV–22
IV–5 Technology Objectives for Electronic Warfare IV–27
IV–6 Technology Objectives for Ground Combat and Tactical Systems IV–35
IV–7 Technology Objectives for Weapons IV–43
IV–8 Technology Objectives for Soldier and Personnel Technologies IV–53
IV–9 Technology Objectives for Biomedical IV–63
IV–10 Technology Objectives for Chemical/Biological Defense IV–73
IV–11 Technology Objectives for Engineering, Combat Construction, Mobility, and Countermobility IV–79
IV–12 Technology Objectives for Logistics IV–86
IV–13 Technology Objectives for Materials, Material Processes, and Structures IV–94
IV–14 Technology Objectives for Sensors and Electronics IV–106
IV–15 Technology Objectives for Battlespace Environment IV–120
IV–16 Technology Objectives for Biotechnology IV–127

CHAPTER

IV APPLIED RESEARCH (TECHNOLOGY DEVELOPMENT)

A INTRODUCTION

This chapter describes the Army's key applied research investments in higher risk, potential leap-ahead technologies to enable the Objective Force and transform the Army. The thrust is to capitalize on basic research and technology opportunities, reduce technology barriers, and exploit options for essential new battlefield capabilities.

The Army applied research investment is the vital enabler of advanced concepts, and it is the critical link in translating the potential of the Army's basic research (Chapter V) into the applications for new components, models, and concepts. These are focused to accelerate investments and demonstrations of critical technologies. The linkage between the Chapter IV mission/thrust areas and the Objective Force technology areas they support are shown in Table IV–1.

TABLE IV–1. MISSION AREA AND TECHNOLOGY THRUST AREA LINKAGES TO OBJECTIVE FORCE TECHNOLOGY AREAS

Mission Areas and Technology Thrust Areas	Objective Force Technology Areas									
	FCS	C^4ISR	Survivability	Lethality	Medical	Rotorcraft	Future Warrior	Personnel Technology	Advanced Simulation	Logistics Reduction
MISSION AREAS										
Aviation	●		○	●		●		○		○
Command, Control, Communications, and Computers		●				○			●	●
Electronic Warfare		●				●				
Ground Combat and Tactical Systems	●									●
Weapons			●	●		●				●
Soldier and Personnel Technologies	○	○	○				●	●		●
Biomedical					●					
Chemical/Biological Defense			●							
Engineering, Combat Construction, Mobility, and Countermobility	●	●	●	●			○			●
Logistics						○				●
TECHNOLOGY THRUST AREAS										
Materials, Material Processes, and Structures			●			○				●
Sensors and Electronics		●				○				●
Battlespace Environment		●								
Biotechnology					●					

● Primary ○ Secondary

The chapter taxonomy reflects 10 mission areas and 4 technology thrust areas. Together these areas provide the technologies required for an integrated, full-spectrum operational Objective Force. Each area comprises key technology subareas addressing goals and major technical challenges. For each mission/thrust area, a table of technology objectives lists significant planned accomplishments for the near, mid, and far term.

The 10 mission areas are defined below:

- *Aviation*—rotary-wing vehicle and propulsion technologies that will give the warfighter the sustained capability to move forces more rapidly, with greater efficiency and reliability, and with a reduced logistics burden.
- *Command, Control, Communications, and Computers*—technologies needed for a robust and flexible architecture to enable enhanced decisionmaking and seamless, assured communications.
- *Electronic Warfare*—technologies that address the increasingly vital need for electromagnetic spectrum dominance.
- *Ground Combat and Tactical Systems*—technologies that support vehicle systems integration, chassis and turret structure development, integrated survivability, mobility, vehicular electronics, and robotics.
- *Weapons*—technologies for armament, munition, missile, and air and missile defense, including radio frequency, directed-energy weapons.
- *Soldier and Personnel Technologies*—technologies that aim to increase the warfighting capability for the soldier by focusing on the human element.
- *Biomedical*—technologies concerned with chemical and biological warfare agents, natural infectious diseases, toxic contaminants, trauma, and stress.
- *Chemical/Biological Defense (CBD)*—nonmedical CBD technologies, including contamination avoidance and protection, decontamination, and modeling and simulation.
- *Engineering, Combat Construction, Mobility, and Countermobility*—technologies supporting civil engineering, environmental quality, mobility, and countermobility..
- *Logistics*—Army applied research that highlights activities of significant logistical benefit.

The four technology thrust areas are as follows:

- *Materials, Material Processes, and Structures*—technologies supporting materials survivability, life extension, and affordability.
- *Sensors and Electronics*— technologies supporting the broad range of sensors (radar, electro-optic, acoustics, seismic, magnetic, etc.) and electron devices such as focal plane arrays and advanced displays.
- *Battlespace Environment*—the study, characterization, and prediction of terrestrial and lower atmosphere environments, including topographic research.
- *Biotechnology*—the new science of molecular biology and bioprocess engineering.

The National Research Council's Board on Army Science and Technology, Defense Science Board (DSB), Army Science Board (ASB), Army in-house S&T community, and Training and Doctrine Command (TRADOC) battle laboratories and schools have all recommended a sustained focus on "critical" technologies that will eliminate the major barriers to the most promising state-of-the-art advances. The Army 6.2 investment is committed to this. Although its main focus is providing capabilities for land force dominance, the Army investment is also synchronized with DoD-wide S&T investments.

The Army applied research mission and technology thrust areas support the DoD *Defense Technology Area Plan* (DTAP) as shown in Table IV–2.

TABLE IV–2. MISSION AREA LINKAGES TO DTAP TECHNOLOGY AREAS

Mission Areas and Technology Thrust Areas	DTAP Technology Areas									
	Air Platforms	Ground & Sea Vehicles	Chemical/ Biological Defense	Materials/ Processes	Human Systems	Information Systems	Biomedical	Weapons	Sensors, Electronics, Electronic Warfare	Battlespace Environment
MISSION AREAS										
Aviation	●				●			○	○	
Command, Control, Communications, and Computers						●				
Electronic Warfare									●	
Ground Combat and Tactical Systems		●								
Weapons								●		
Soldier and Personnel Technologies					●					
Biomedical							●			
Chemical/Biological Defense			●							
Engineering, Combat Construction, Mobility, and Countermobility								●		
Logistics				●						
TECHNOLOGY THRUST AREAS										
Materials, Material Processes, and Structures				●						
Sensors and Electronics									●	
Battlespace Environment										●
Biotechnology										

● Primary ○ Secondary

Note: There are no Army applied research programs in the Nuclear Technology or Space Platforms DTAP technology areas.

B STRATEGY

The Army 6.2 program identifies and focuses on selected technologies that will provide the maximum warfighting capability for every dollar invested. This demands a significant dual commitment to in-house Army applied research and to the expansion of cooperative efforts with the other services and industry. The Army leverages research and technology opportunities in academia, industry, and the international community to promote efficiency and synergy at all levels. (See Annex F, Infrastructure, for a more detailed discussion of the federated laboratories.) The technology leveraging and transfer program is discussed more fully in Chapter VI, Technology Transfer.

The Army science and technology (S&T) oversight process prioritizes technology needs and opportunities based on their potential to provide critical battlefield capabilities. The developers jointly define these capabilities. The early and continuous involvement of the warfighter in the S&T capabilities definition process allows for a balanced look at the "technology push" coming from the Army's S&T community, and the "requirements pull" prompted by the needs of the warfighter. This alignment is promoted by the dialog that occurs between the combat developers and materiel developers during the Army Science and Technology Objective (STO) reviews and the TRADOC S&T reviews. These take place in the spring and summer and result in an S&T program that is attuned to the warfighter's evolving vision of the future. The input from integrated idea teams and annual simulated future technology wargames serves to enhance the relationship between the combat and the materiel developers. The traditional workings of this process have been substantially streamlined to respond to the Chief of Staff's vision for a more mobile, powerful, and deployable Objective Force.

Approximately 60 percent of the Army's applied research funds are invested in STO programs. This approach provides the means to focus and accelerate promising emerging technologies toward near- and mid-term transitions, while allowing discretionary investigation of high-payoff, but high-risk, technology opportunities.

Each section in this chapter is structured to define the area of technology, summarize the Army's ongoing technological work, and provide a forecast of future capabilities. The years shown on each technology objectives table approximate key aspects of the Planning, Programming, Budgeting, and Execution System process timetable. FY01–02 relates to the budget years, FY03–08 addresses the program objective memorandum (POM) time period, and FY09–16 covers the Army research, development, and acquisition (RDA) plan. A clear and consistent S&T program is maintained through aggressive management of the Army STOs. The Army STOs associated with this chapter are described in Volume II, Annex A.

C AVIATION

This section is organized by six aviation technology subareas, which comprise the platform technologies that are essential to the development of an aircraft. Under Project Reliance, the Army is the lead for DoD S&T in aeromechanics, drive systems, flight control, structures, subsystems, and small gas turbine engines supporting the development of military rotary-wing vehicles (RWVs). Mission equipment may then be added to perform missions required of the aircraft system. Each of the descriptions of the six technology subareas includes goals and challenges that must be overcome to achieve advances needed to meet Objective Force capabilities.

The Army is undergoing a major evolution in its doctrine, organizational requirements, and priorities based on the Army vision. Army aviation is a key enabler for the Army vision and is strategically responsive by either self-deployment or strategic lift. When employed as a part of a joint force or as a part of the army combined arms team, aviation systems provide the joint force or land force commanders a sustainable capability to move rapidly, focus combat power on multiple targets, and enhance near-real-time situational awareness.

Affordability and dual-use considerations in rotorcraft technology development have become increasingly important in shaping Army aviation's investment strategy. From a dual-use perspective, civil and military rotorcraft communities have a mutual stake in all but very few areas of rotorcraft technological research (e.g., survivability in battlefield environments, lethality). Improvements in handling qualities, vibration, and sound-level reductions are important to both civil and military rotorcraft operators.

The Army's investments in support of the DoD Integrated High-Performance Turbine Engine Technology (IHPTET) program focuses on technologies that will result in turboshaft and turboprop engines and components that are more compact, lighter in weight, higher in horsepower, more fuel efficient, and lower in cost than those currently available. Army gas turbine propulsion technology is developed jointly and in close coordination with the other military services, NASA, and industry, thus inherently promoting efficiency and dual-use S&T and processes.

The S&T program enables Army aviation by providing the knowledge needed to upgrade existing aircraft or to develop new aircraft to meet the mission requirements imposed by a changing world situation. Future Army missions will require aircraft capable of flying farther, flying for longer mission duration, increasing lift capability, surviving more robust and dispersed threats, defeating a wider spectrum of targets in more varied environmental and topographical settings, and imposing less logistical demand on supply and maintenance resources. The following paragraphs describe the effort to achieve these goals for the future transport rotorcraft (FTR), next-generation rotorcraft concepts, and potential upgrades for current aircraft systems through technology insertions to sustain combat overmatch and extend operational lives.

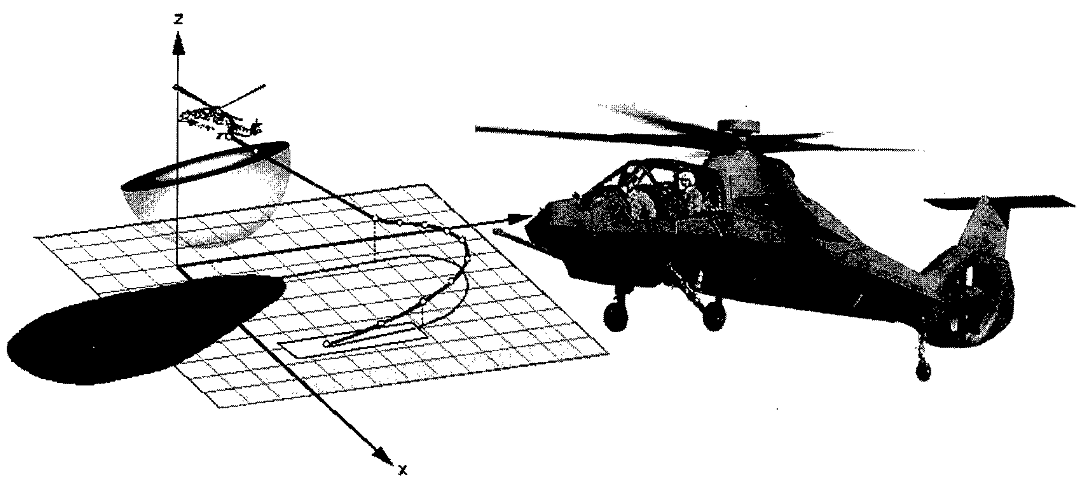
Technology Subareas

The Army aviation applied research program is structured around six subareas: Aeromechanics, Flight Control, Structures, Subsystems, Rotorcraft Drive, and Propulsion.

AVIATION-RELATED STOs
Aeromechanics
Advanced Rotorcraft Aeromechanics Technology (ARCAT)
Variable-Geometry Advanced Rotor Technology (VGART)
Low-Cost Active Rotor (LCAR)
Flight Control
Rotorcraft Open Systems Avionics
Subsystems
Rotorcraft Enhanced Survivability Technologies (REST)

1 Aeromechanics

Aeromechanics technology addresses acoustics, aerodynamic performance, rotor loads, vibration, maneuverability, and aeroelastic stability. It seeks to improve rotorcraft performance while reducing noise, vibrations, and loads (Figure IV–1).



Graphic depicts rotorcraft noise modeling (RNM), coupled with commercially available optimizer, to develop alternative low-noise flight procedures. Validated in 1999 and demonstrated readiness of RNM for application.

FIGURE IV–1. AEROMECHANICS TECHNOLOGY

Goals

Three STOs are associated with the Aeromechanics subarea. These STOs will contribute to rotorcraft system payoffs in range, payload, cruise speed, maneuverability and agility, reliability, maintainability, and reduced operating costs.

ADVANCED ROTORCRAFT AEROMECHANICS TECHNOLOGIES (ARCAT) STO. The ARCAT program will use on-blade active controls to increase rotor blade performance and aerodynamic efficiency and reduce noise, blade loads, and vehicle vibration.

VARIABLE-GEOMETRY ADVANCED ROTOR TECHNOLOGY STO. The VGART program will employ a variable-geometry rotor system (which is an option for the FTR) to reduce vibration and increase maximum blade loading. The high-risk rotor concepts have critical subcomponent (e.g., on-blade

actuators) and scaling barriers that must be addressed. Immediate technical benefits include a 30 percent reduction in rotorcraft vibration and a 10 percent increase in rotor max blade loading. Successful laboratory demonstrations will allow for leap-ahead platform performance and affordability. The goal is to complete bench tests and to define criteria and subcomponent fidelity parameters for application to a flight demonstrator by the end of FY01. The Objective Force enhancement resources will be used for large-scale critical component fabrication testing and analysis for the promising concept of the variable diameter rotor. The technology readiness level (TRL) will improve from a 4 to a 5 for ARCAT and VGART. *Supports:* FTR.

LOW-COST ACTIVE ROTOR (LCAR) STO. The LCAR program has the goal of transitioning to rotor on-blade control for a no-swashplate helicopter demonstration program. The no-swashplate helicopter has great potential for reduction in operating costs as well as improved performance. The TRL will improve from a 2 to a 4 for LCAR.

Challenges

The technology challenges for the aeromechanics S&T program include rotor systems having unacceptably high vibrations and high noise levels and low aerodynamic performance. Computer codes and models for advanced rotor system designs are needed for the FTR and other next-generation rotorcraft concepts. Smart rotor structures are needed to increase rotor efficiency and reduce vibration. High-potential rotor blade control techniques for active flaps, variable diameter rotors, and active twist rotors must be modeled in a computer, built in scale model, and tested in wind tunnels to verify the models.

2 Flight Control

Flight control technology addresses the interface between aircraft and pilot to achieve improved handling during critical mission tasks. Research should focus on synthesized control laws and integrated advanced pilotage systems (Figure IV–2).

Evaluation of Aeronautical Design Standard—33
Using a UH–60A Black Hawk Helicopter

UH–60A decelerating at the end of the Lateral Reposition maneuver.

UH–60 with 6k pound external load performing the Lateral Reposition maneuver.

Graphic depicts validation goals of HACT concepts of tailored control laws and carefree maneuvering, specifically lateral repositioning maneuvers with clean airframe and with slung loads.

FIGURE IV–2. FLIGHT CONTROL TECHNOLOGY

Goals

The goals of the 6.2 flight control program are to develop and validate flight control technologies to support on-blade actuation rotors central to VGART, VGARD, and FTR; use the potential for improved maneuverability and control redundancy of on-blade control actuation to achieve damage tolerance through automatic reconfiguration; and combine onboard vision sensors and GPS navigation with intelligent guidance schemes to achieve autonomous and automated nap-of-the-Earth flight. Key elements of this work are the progressive buildup of on-blade control demonstration from analysis and wind tunnel tests to flight (FTR). The on-blade control algorithm must provide agility and maneuverability while simultaneously achieving reduced loads and vibration. Efficient online methods for system identification are the basis for reconfigurable control architectures. Fast and robust online algorithms must be developed and validated in analysis, and then tested in the wind tunnel. Fuzzy logic concepts are refined that will make the appropriate control reconfiguration decisions once a sensor or actuator failure is isolated. Autonomous control will first be used to make flight-time modifications to preassigned waypoint guidance for application to unmanned rotorcraft. A suite of fuzzy logic rules will be built up based on piloted simulation in the workstation-based simulator (RIPTIDE) that will combine information from the waypoint trajectory with threat or obstacle warning from onboard vision sensors. These algorithms will be initially validated on the R–50 UAV platform. Then, threat and collision avoidance algorithms will be integrated with active stick cueing to provide real-time guidance support to the pilot for manned aircraft applications. These algorithms will be validated on the RASCAL national in-flight simulator.

Products of the 6.2 program flow into the Helicopter Active Control Technology (HACT) demonstration, the next-generation flight control system for rotorcraft. The HACT Flight Control System (HFCS) is a vehicle management system that features task-tailored control laws and carefree maneuvering. Task-tailored control laws allow the pilot to fly the aircraft throughout its operational flight envelope with optimized control augmentation. The HFCS tailors the control system to adjust for various conditions like degraded visual environments and other off-peak performance conditions. Carefree maneuvering allows the pilot to confidently, aggressively fly the aircraft throughout its operational flight envelope by assisting the pilot from inadvertently exceeding aircraft limits and taking advantage of more of the embedded capabilities of the aircraft. Additionally, the program will apply and measure the impact of modern interactive design methods to reduce control system costs for new or modified systems. These active control technologies contribute to goals to increase vehicle maneuverability and agility, reduce accident rates, and lower system operating and support (O&S) costs. The HACT program will use fly-by-wire/-light digital control as part of the vehicle management system to improve rotorcraft control and handling qualities. Through the use of task-tailored control laws, the propulsion, utility, and mission subsystems will be integrated with flight control to improve flightpath guidance. The results include improved weapon pointing accuracy and increased aircraft agility and maneuverability. The TRL will improve from a 3 to a 7 for HACT.

Challenges

The technology challenges for the flight control S&T program include lack of knowledge of optimal rotorcraft response types and optimal integration of flight control, weapon systems, and pilot interface. There are limited techniques for sensing the onset of flight control limits and pilot cueing. Computer models are needed for flight control system design to exploit advances in fly-by-light technology.

3 Structures

Structures S&T aims at improving aircraft structural performance while reducing both acquisition and operating costs (Figure IV–3). The key effort in this subarea is the RWST STO that will include fabrication and demonstration of advanced lightweight tailorable structures and ballistically tolerant airframe configurations.

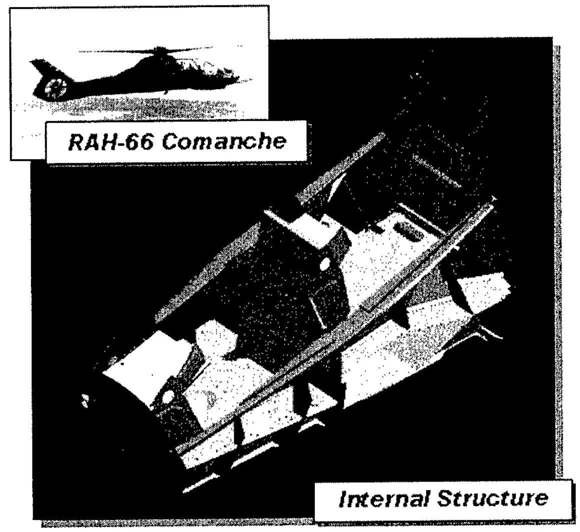
Goals

The subarea goals are to improve structural load prediction accuracy, reduce manufacturing labor costs, improve the producibility of composite and aircraft structural components using automated manufacturing processes, and enable the extensive use of composite structures. The TRL will improve from a 3 to a 6 for RWST.

Challenges

The technology challenges for the structures S&T program include airframe weight reduction, costs of manufacturing labor, and unacceptable structural integrity and durability. There are problems with inaccurate load determination, confidence in primary bonded composite structures, and lack of automation in manufacturing structural components. The use of computer modeling for prototypes is needed to improve design methods for integrating structural elements.

Lower Forward Fuselage Demonstration Article



Graphic depicts composite structural design concept for RAH–66 Comanche with goals of achieving automated manufacturing processes to improve aircraft assembly procedures. The extensive use of composite structures will contribute to aircraft goals of increased range or payload lift capability, increased reliability and maintainability, and reduced operating costs.

FIGURE IV–3. ROTARY-WING STRUCTURES TECHNOLOGY

4 Subsystems

This subarea addresses a broad range of S&T topics related to support, sustainment, and survivability and to the application of high-performance weapons on rotorcraft.

Goals

The subsystems S&T program is organized into two technologies: survivability and prognostics/diagnostics. The survivability technology area is focused on the REST STO, which will demonstrate substantial reduction in aircraft signatures (infrared, electro-optic, visual). The REST program will use infrared suppression concepts to reduce engine exhaust signatures and advanced camouflage and low-glint canopy materials to reduce electro-optic and visual signatures. The goal of REST is to provide a significant improvement in survivability to the aircraft and crew; the TRL will improve from a 3 to a 5. The prognostics/diagnostics technology area is focused on the Joint Advanced Health and Usage Monitoring System (JAHUMS) DTO, which is an ACTD to improve in-flight safety and reliability of helicopters. The JAHUMS program will reduce life-cycle costs, improve system safety and performance, and streamline maintenance and logistics processes in the Army and Navy helicopter communities. The TRL will improve from a 5 to a 7 for JAHUMS.

Challenges

The technology challenge for the aviation survivability S&T program is reducing the threat from man-portable air defense missile systems. Additional challenges arise in reducing this threat due to the use of components that increase the weight and cost of the aircraft and include associated engine performance penalties. For prognostics/diagnostics S&T, the technology challenge is to implement an acceptable monitoring system that is compatible with the independent technology modules onboard the aircraft using an open systems architecture approach. In addition, the digital data that the JAHUMS produces must be integrated with the existing maintenance systems in the Army and Navy.

ROTORCRAFT ENHANCED SURVIVABILITY TECHNOLOGIES (REST) STO (2000–03). This STO focuses on the development, integration and demonstration of improved RWV survivability through control of critical signature sources being exploited by advanced man-portable air defense (MANPADS) threats. The proliferation of these lethal man-portable, surface-to-air missile systems have resulted in the need for a better equipped, lower IR signature aircraft. Technology objectives are aimed at reducing the IR and visual signatures representative of current fleet aircraft. Reduction in the visual signatures of aircraft will delay acquisition by the MANPADS operator, which has the effect of reducing the effective range of the MANPADS weapon system. Engine exhaust hot metal and plume signature reductions will be accomplished through the development of an advanced engine IR suppressor sized for a T–700-class engine. Airframe IR signature reduction will be accomplished through development of super-lightweight thermal insulation to control concentrated thermal loads near engine bays and transmissions. Reduced visual signature will be accomplished through the development of improved camouflage for use against low-altitude terrain backgrounds, and the development of low-glint canopy coatings. Advanced engine suppression concepts will be fabricated and demonstrated in full-scale ground test hardware by FY01 and flight-tested by FY02. Super-lightweight insulation will be demonstrated on a flight aircraft by FY02. Advanced camouflage and low-glint canopy coatings will be operationally demonstrated in FY03. A goal of 50 percent reduction in aircraft IR and visual signatures is attainable and anticipated, which will support an RWV payoff of 40 percent increase in the probability of survival (Figure IV–4). *Supports:* Aviation systems, Project Reliance, multiservice applications.

5 Rotorcraft Drives

Rotorcraft drives technology addresses prime power transmission systems and components that are more compact, lighter in weight, higher in horsepower, more efficient, and less costly than current systems (Figure IV–5).

Goals

The RDS–21 STO will integrate emerging technologies in materials, structures, mechanical components, dynamics, acoustics, lubrication, and manufacturing processes to improve the performance and affordability of large rotorcraft drive systems. The RDS–21 program goal is to provide efficient power transfer with minimum system weight and increasing reliability. In achieving that goal, it is expected that improvements will be made in aircraft lift capability while reducing noise, operating costs, and manufacturing costs. Components and system-level validations will be performed to validate advanced computer models of the rotorcraft drive system. The TRL will improve from a 4 to a 6 during RDS–21.

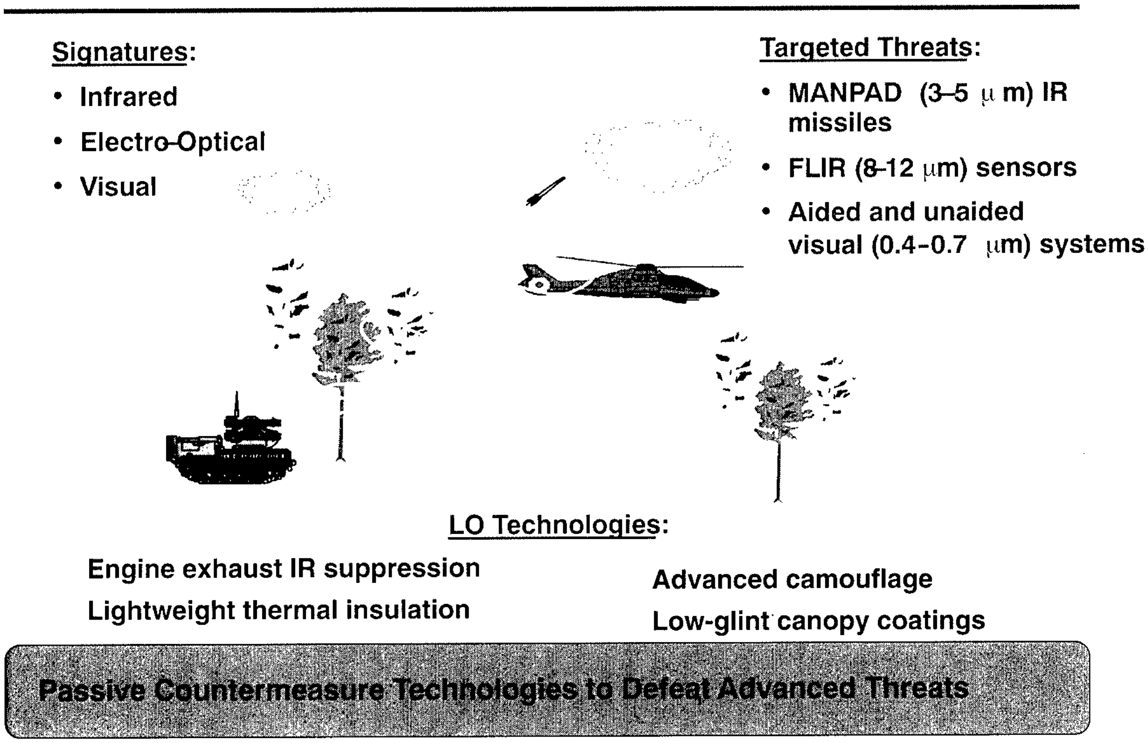
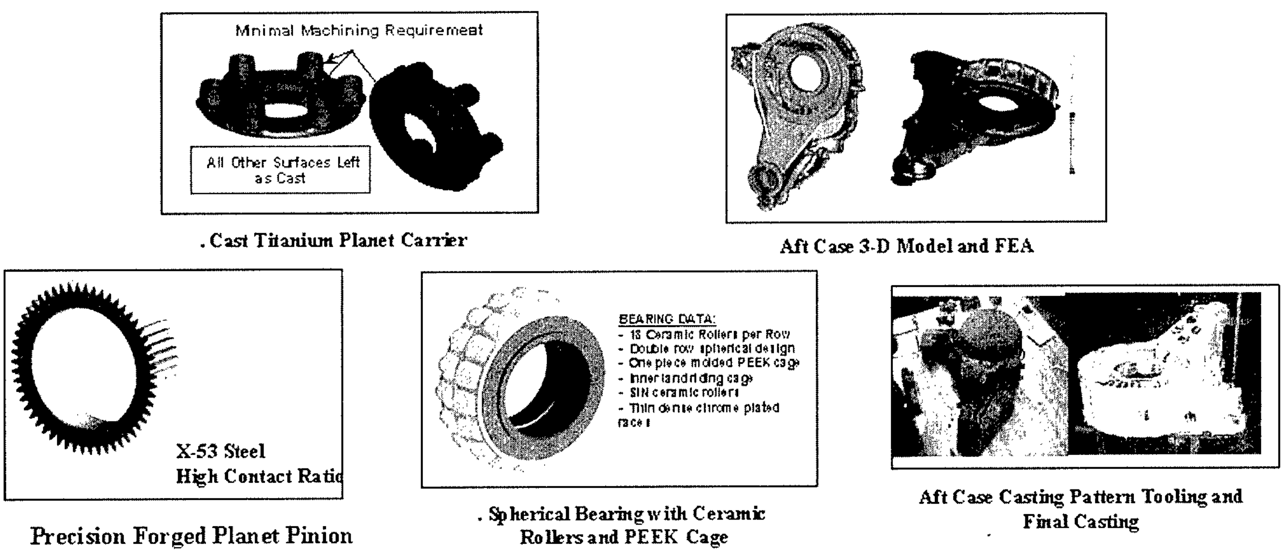


FIGURE IV–4. ROTORCRAFT ENHANCED SURVIVABILITY TECHNOLOGIES



Cast Titanium Planet Carrier

Aft Case 3-D Model and FEA

Precision Forged Planet Pinion

Spherical Bearing with Ceramic Rollers and PEEK Cage

Aft Case Casting Pattern Tooling and Final Casting

FIGURE IV–5. ROTORCRAFT DRIVE TECHNOLOGY

Challenges

The technology challenges for the rotorcraft drive S&T revolve around removing system weight while increasing reliability and minimizing vibration to enable increased payload and range of the aircraft. Drive systems are expensive to maintain, and they produce damaging noise levels. Improvements are needed in design, tools, and materials used in the drive system. Fewer moving parts, improved lubricants, concepts enabling equal load path sharing, and fewer gear reduction stages are important challenges to the drive system goal.

6 Propulsion

Propulsion addresses engine component and system technologies for small gas turbines (turboshaft and turboprop) to reduce fuel consumption while increasing power output (Figure IV–6).

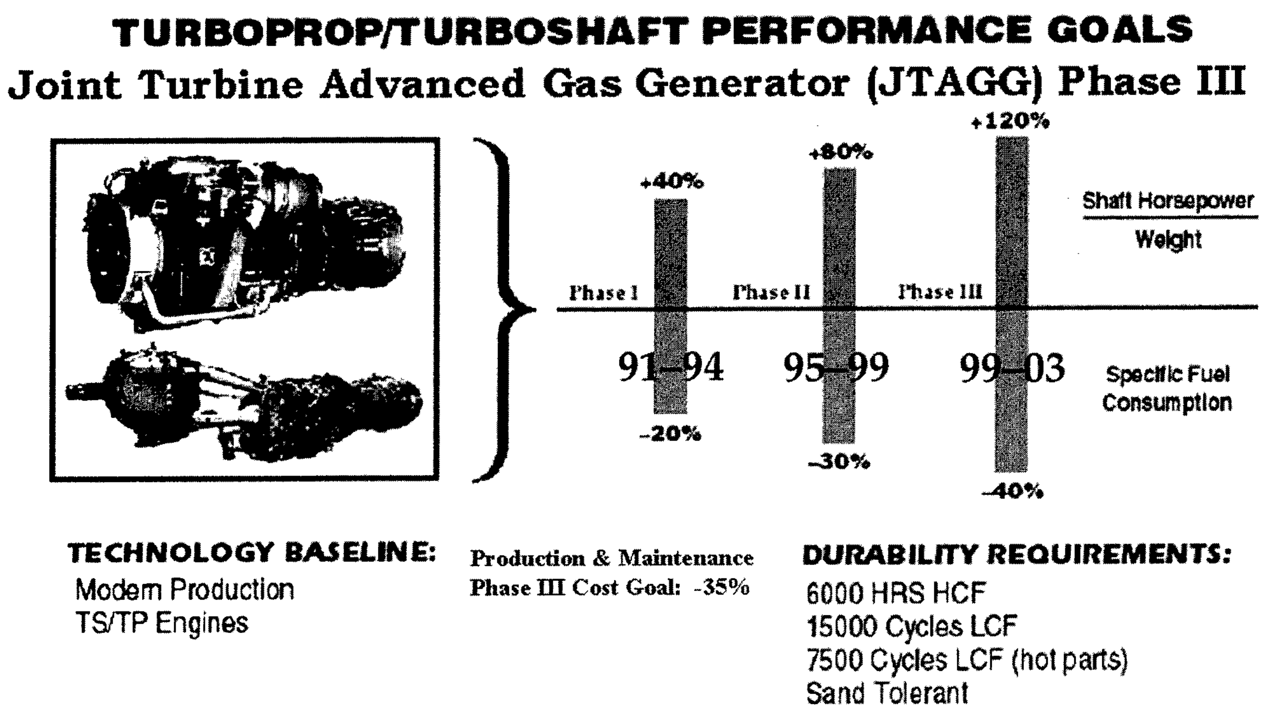


FIGURE IV–6. INTEGRATED HIGH-PERFORMANCE TURBINE ENGINE TECHNOLOGY INITIATIVE

Goals

Army applied research provides key support to the Joint Turbine Advanced Gas Generator III (JTAGG III) STO under the DoD-, NASA-, DARPA-sponsored IHPTET initiative. The subsequent FTR Engine S&T Demonstrator will develop and demonstrate advanced rotorcraft propulsion technology for improved air vehicle performance (payload and range capability) and reduced O&S costs and logistical burden in support of the future Objective Force. Specific JTAGG III goals will be to effectively double the propulsion system capability by 2003 through demonstration of a 40 percent reduction in specific fuel consumption, a 120 percent increase in shaft horsepower (Shp)/weight ratio, and a 35 percent reduction in production and maintenance costs for turboshaft engines in the 10,000-Shp class. This will involve the integration of emerging technol-

ogies in the areas of structures, controls, aerodynamics, advanced materials, and accessories, which provide reduced vulnerability, improved reliability and maintainability, and high levels of readiness and mission success. Small-engine demonstrator programs will address far-term goals (FY06–16 timeframe), which include a 40 percent reduction in specific fuel consumption, a 120 percent increase in Shp/weight ratio, a 20 percent reduction in development costs, and a 35 percent reduction in power and maintenance costs for turboshaft engines, which are less than or equal to 3,000 Shp.

Challenges

Doubling propulsion capability requires higher temperatures at combustion initiation, higher maximum cycle temperature, reduced specific weight, increased component efficiencies, effective control of cooling air in small blades and vanes, centrifugal impeller aerodynamics, and operation at higher rotor speeds. These same challenges are more severe and require different technologies and component configurations for small rotorcraft engines than for large rotorcraft engines due to clearance effects, manufacturing limitations, etc.

National Rotorcraft Technology Center

The National Rotorcraft Technology Center (NRTC) is a consortium of government, academia, and industry that focuses resources in an innovative research partnership toward the strategic goals of continued superiority of U.S. military rotorcraft and expanding the world rotorcraft market and U.S. industry's market share. It emphasizes cooperation, sharing, streamlined processes, and minimal infrastructure. NRTC uses a two-pronged program approach: the Rotorcraft Industry Technology Association unifies U.S. rotorcraft industry through a nonprofit company, and the Rotorcraft Center of Excellence focuses academia on government- and industry-identified needs. The major functions of the NRTC are to develop critical rotorcraft technologies; facilitate development of a national rotorcraft strategy; provide information interchange; strengthen academic capability; and serve as a national management model for government, industry, and academia collaboration (Figure IV–7).

Technology Objectives

Aviation technology objectives are shown in Table IV–3.

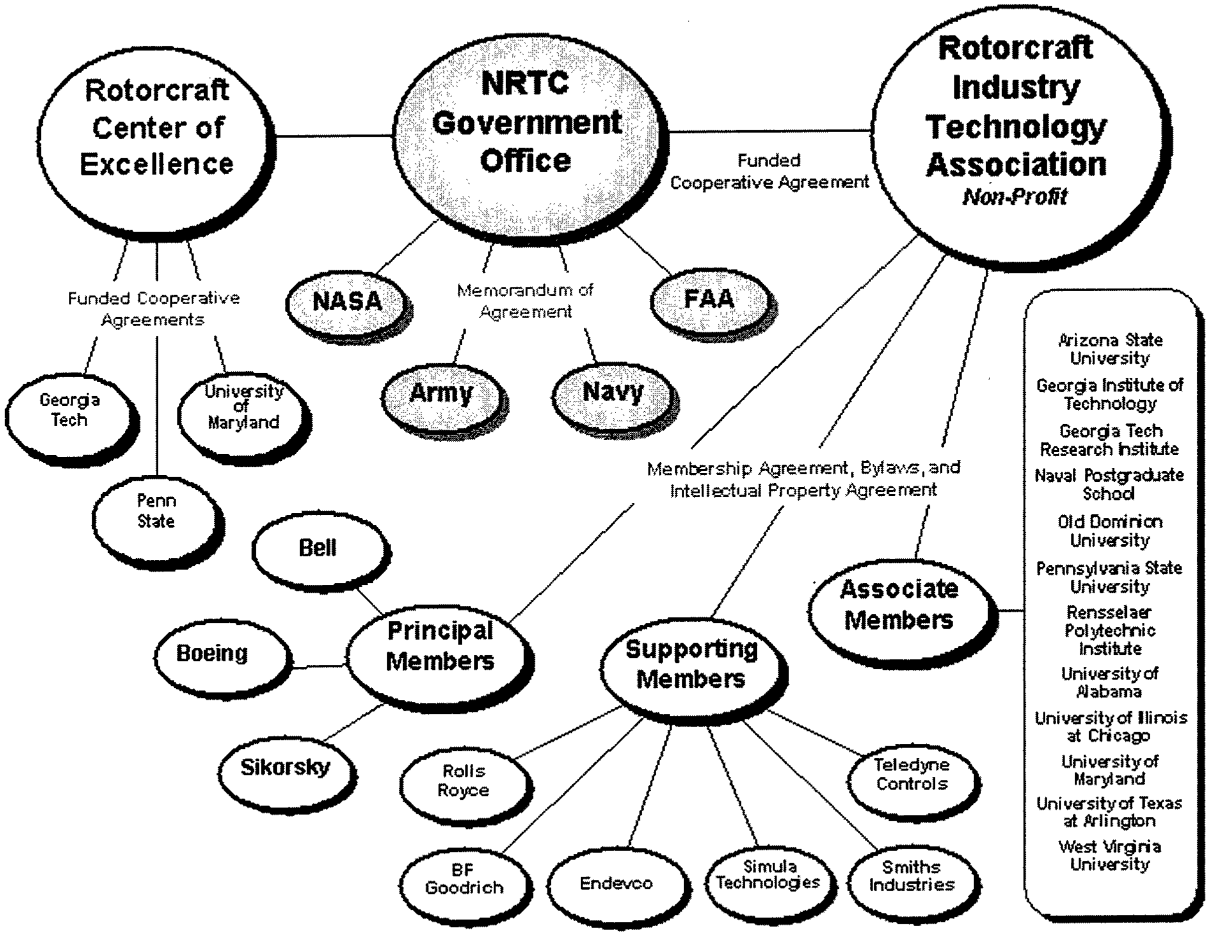


FIGURE IV–7. ORGANIZATION OF THE ROTORCRAFT CENTER OF EXCELLENCE CONCEPT AND THE NATIONAL ROTORCRAFT TECHNOLOGY CENTER

TABLE IV–3. TECHNOLOGY OBJECTIVES FOR AVIATION

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Aeromechanics	Aeroacoustic & aeroelastic prediction codes verified & incorporated in comprehensive analysis Rotor–fuselage interaction CFD-unique experiments conducted High-lift rotor concepts evaluated Low-cost, high-efficiency rotor design methodology initiated CFD/inflow analysis verified	Reduce vibratory loads by 40% Reduce vehicle adverse aerodynamic forces by 12% Increase maximum blade loading by 16% Increase helo/rotor aerodynamic efficiency by 6% Reduce acoustic detectability range by 50% Increase prop/rotor aerodynamic efficiency by 3% Increase rotor inherent lag damping by 66% Increase aeromechanic prediction effectiveness by 75%	Reduce vibratory loads by 60% Reduce vehicle adverse aerodynamic forces by 20% Increase maximum blade loading by 24% Increase helo/rotor aerodynamic efficiency by 10% Reduce acoustic detectability range by 75% Increase prop/rotor aerodynamic efficiency by 4.5% Increase rotor inherent lag damping by 100% Increase aeromechanic prediction effectiveness by 85%

TABLE IV–3. TECHNOLOGY OBJECTIVES FOR AVIATION (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Flight Control	Establish cargo/slung load flight test maneuvers; conduct simulations to develop criteria for hover & low speed Complete terrain-correlated turbulence model Develop & transition advanced control law synthesis techniques Complete CIFER UNIX upgrade & train industry Complete IFFC piloted ground simulations Develop techniques for pilot-envelope cueing & limiting	Improve platform flightpath pointing & accuracy by 65% (attack only) Improve external load handling qualities at night by 185% (cargo only) Reduce probability of degraded handling qualities due to flight control system failures by 65% Improve handling qualities at night with partial actuator authority CHPR 3 Increase precision maneuvering at extreme load factors by 40% Reduce flight control system flight test development time by 35%	Improve platform flightpath pointing & accuracy by 80% (attack only) Improve external load handling qualities at night by 225% (cargo only) Reduce probability of degraded handling qualities due to flight control system failures by 90% Improve handling qualities at night with partial actuator authority CHPR 3 Increase precision maneuvering at extreme load factors by 66% Reduce flight control system flight test development time by 50%
Structures	Define RWST structured configuration & requirements Select critical components for development, testing, & demonstration in RWST Complete fabrication & testing of RTM trial beam for RAH–66, TP horizontal stabilizer for OH–58D, & TP tailboom section for the RAH–66 baseline TP horizontal stabilizer & TP tailboom section for the RAH–66 Develop system architecture for MATES & preliminary design concept for damage tolerant hub fixture for RAH–66 baseline Initiate the harmonization of civil & military design requirements, specifications, standards, & the application & refinement of IPPD principle to reduce LCCs	Reduce (structural component weight)/GW by 15% Reduce structures manufacturing, LH/lb, by 25% Reduce structural component development time by 25% Reduce dynamically loaded structure stress prediction inaccuracy by 30%	Reduce (structural component weight)/GW by 25% Reduce structures manufacturing, LH/lb, by 40% Reduce structural component development time by 40% Reduce dynamically loaded structure stress prediction inaccuracy by 50%
Subsystems	90% P_d of impending failures of structural components 20% increased operational durability & repairability of reduced signature materials 15% reduction in IR & visual EO vehicle signatures 10% increase in ballistic & NBC hardening technique	Reduce 0.4–0.7-μm visual signature by 50% Reduce 3–5-μm IR signature by 50% Reduce 8–12-μm IR signature by 50% Reduce threat protection weight/GW by 10% Reduce total maintenance labor by 30% Autodetect critical mechanical components by 60%	Reduce 0.4–0.7-μm visual signature by 60% Reduce 3–5-μm IR signature by 60% Reduce 8–12-μm IR signature by 60% Reduce threat protection weight/GW by 20% Reduce total maintenance labor by 45% Autodetect critical mechanical components by 75%
Rotorcraft Drives	Hardened/ground face gears manufactured & rig tested Seeded fault diagnostic/prognostic spiral bevel gear tests	Increase drive system power-to-weight ratio by 33% Reduce drive system production cost, \$/mh, by 20% Reduce drive system operating cost, \$/fh, by 20% Reduce transmission-generated noise by 15 dB	Increase drive system power-to-weight ratio by 40% Reduce drive system production cost, \$/mh by 30% Reduce drive system operating cost, \$/fh by 30% Reduce transmission-generated noise by 15 dB
Propulsion	High-efficiency, high-pressure ratio, dual-alloy centrifugal impellers Characterization of startup process of nontraditional compression systems Nonintrusive ignition Turbines with high cooling effectiveness airfoils Nonmetallics for combustor & turbine applications Hybrid ceramic bearings, magnetic bearings	For 10,000-Shp-class engine: • Reduce specific fuel consumption by 40% • Increase Shp/weight ratio by 120% • Reduce production cost by 35% • Reduce maintenance cost by 35%	For <3,000-Shp-class engine: • Reduce specific fuel consumption by 40% • Increase Shp/weight ratio by 120% • Reduce development cost by 20% • Reduce production cost by 35% • Reduce maintenance cost by 35%

D COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS

Command, control, communications, and computers (C^4) is the Army's force multiplier for the digitized battlefield of the 21st century. Synonymous with "information superiority" as defined by the Chairman, Joint Chiefs of Staff, C^4 "is the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary's ability to do the same." The Army's applied research (6.2) program in C^4 aligns with the *Defense Technology Area Plan,* Information Systems Technology area, and the Information Superiority Joint Warfighting Capability Objective presented in the *Joint Warfighting Science and Technology Plan.* These programs develop the technologies and architectures needed to provide warfighters with the right information, in the right place, at the right time. To accomplish this, there must be flexible architectures that allow:

- Common software for a variety of decisionmaking toolkits.
- Modeling and simulation (M&S) technologies that facilitate early assessment of new technologies and warfighting analyses, enhance the ability to "view" systems and immerse humans in the virtual world, and facilitate more effective use of M&S technology for training and mission rehearsal.
- Information assurance and distribution among heterogeneous systems.
- Seamless communication systems using commercial and common protocols (allowing transport of information anywhere in the world).
- Computing and software technology that supports the evolution of products inserted into common systems.

Technology Subareas

The Army's C^4 applied research program is structured around two technology subareas: Decisionmaking and Seamless Communications. Information assurance technology initiatives are covered under seamless communications.

C^4-RELATED STOs
Decision Making
Collaboration Technology for the Warfighter
Advanced Battlefield Processing Technology
Seamless Communications
Personal Communications for the Soldier
Dynamic Readdressing and Management for Army 2010 (DRAMA)
Free-Space Optical Communication System
Antennas for Communications Across the Spectrum
Dismounted Warrior C^4I Technologies

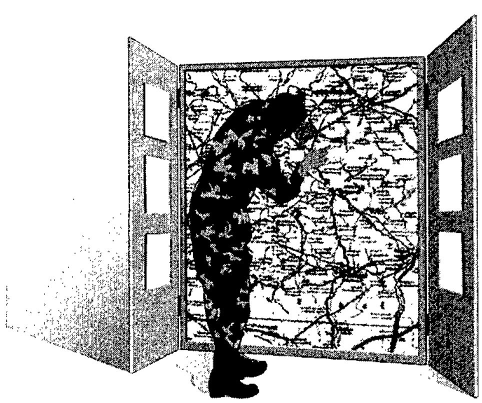
1 Decisionmaking

Decisionmaking is the heart of the command process and affords the warfighter consistent battlespace understanding, forecasting, planning and resource allocation, and integrated force and execution management. Decisionmaking encompasses the development of common, modular components that weave together joint mission planning, rehearsal, execution monitoring, and common pictures of the battlespace. The major emphasis is on acquiring and assimilating infor-

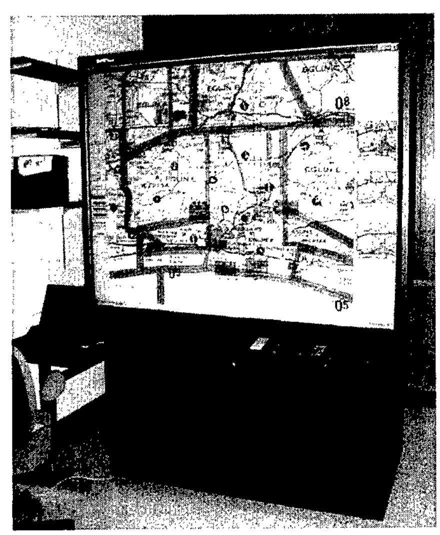
mation needed to dominate and neutralize adversary forces. A key capability is near-real-time awareness of the location and activity of friendly, adversarial, and neutral forces throughout the battlefield area, which provides a common awareness of the current situation. A primary objective of information dominance is to meet the warfighters' needs for a flexible command structure that can be rapidly configured and dynamically adapted to optimize force effectiveness and survivability. The warfighter will be provided an intuitive view of the battlespace—an enlightened perspective of information, and the ability to explore alternatives in faster than real time (e.g., exploring 10-hour battles in several minutes).

Goals

The goal is to provide—over the next decade—automated, real-time decision support to the warfighter. Meeting this goal will enable fundamental changes in military C^2 processes to improve the speed of command and the quality of decisions, thereby ensuring a consistent understanding of the evolving or likely to evolve situation in the battlespace. The warfighter must rapidly interpret information received through interactive two- and three-dimensional presentations of the tactical situation. The commander will have the capability to view relevant forecasts for weather, enemy strength over time, friendly strength, and logistics tail; conduct a course of action analysis; allocate resources; conduct wargames (real-time simulations) to explore battlespace options; and collaboratively plan and rehearse battles. Army laboratories and centers are pursuing several enabling technology programs. Areas of concentration include data and information fusion, rule bases, machine reasoning, fuzzy logic for near-real-time reasoning, intelligent agents, uncertainty visualization and management, and distributed, dynamic component-based architectures for rapid response to crises. The Commander's Decision Associate, Advanced Navigation Technology for C^4ISR, Collaboration Technology for the Warfighter STO (see Figure IV–8), Objective Force Robotics Systems C^2, Advanced Battlefield Processing Technology STO, and the Infor-



Soldiers traditionally operated with cumbersome paper maps and stick-ons



Smart boards can share information between dispersed battlefield locations, enhancing concurrent multiechelon C^2

The electronic smart board speeds human decision making by automating updates of the tactical situation through electronically generated media

FIGURE IV–8. COLLABORATION TECHNOLOGY FOR THE WARFIGHTER

mation Operations Virtual and Live Simulation Environments programs are just a few of the Army's technology initiatives in support of the Future Combat Systems (FCS) and the Objective Force.

Challenges

The challenges are to develop applications that employ intelligent agents for intelligent information retrieval, fusion, and presentation; fuse planning information with actual information in real time; provide real-time simulation (wargaming), planning, and rehearsal on tactical platforms to represent high-fidelity battle outcomes; provide decision support in the presence of uncertain or incomplete information, or the absence of information; develop applications for dynamic scheduling and coordination of assets for interdependent tasks; and provide collaboration tools that permit the spectrum of operations to be performed by remote, dispersed elements of a task force (Figure IV–9).

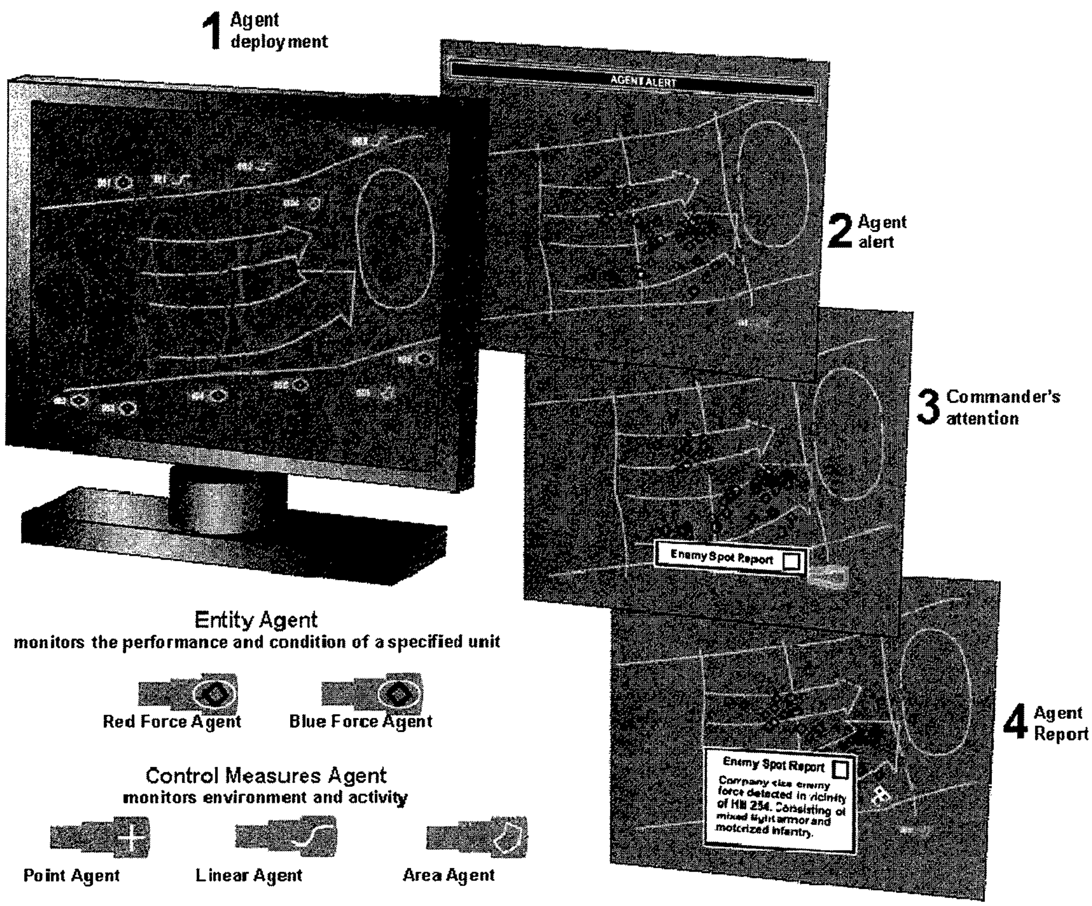


FIGURE IV–9. INTELLIGENT AGENTS VISUALIZATION

2 Seamless Communications

Seamless communications connotes assured, user-transparent, secure connectivity among globally dispersed forces—down to the lowest echelon foot soldier or marine, and to each ship and aircraft. Seamless communications will be accomplished using a combination of U.S. govern-

ment, foreign government, and commercial infrastructures, as well as military surface- and space-based networks operating over a wide range of frequencies. A range of transmission media, bandwidth, standards, and protocols will be accommodated automatically by the networks. Voice and all types of data (e.g., text, graphics imagery, video) will be handled within a uniform information transport infrastructure. These technologies will provide the commander with high-capacity, flexible, and tactical communications to serve all categories of users (including mobile) and satisfy the need for high-confidence communications regardless of system limitations throughout all phases of the battle.

The success of the FCS concept is heavily dependent on the ability to provide an assured networked communications grid. From the network user's perspective, the communications grid will appear as one homogeneous communications asset. Implementation of the grid will be realized via a multitiered communications architecture providing wide-area coverage and allowing an FCS-equipped force to traverse large areas while maintaining connectivity. Seamless communications support split-based operations by spanning the globe and interconnecting command echelons, services, and allies worldwide through common transport protocols and dynamic network management. Emphasis is on universal and assured communications, network management, smart radios, antenna technology, and heterogeneous transmission systems (i.e., wired and wireless). By focusing on wideband capabilities linked to narrowband tactical systems, commanders can provide the necessary critical information to the warrior anywhere in the world. Seamless communications facilitate the warfighters' needs for FCS information, dominance, information warfare, real-time logistics control, and military operations on urbanized terrain (MOUT). Communications is the mechanism to achieve secure, reliable, timely, and survivable C^2 and superior battlefield knowledge.

Goals

The goal is an affordable, survivable, self-managing, multilevel secure, multimedia, multimode and multiband communications system that provides the warfighter with user-transparent connectivity for both analog and digital command, control, and intelligence (C^2I) systems data over the entire combat and garrison operational continuum. The desired communications system must fully support wide- and narrowband on-the-move (OTM) C^2I data and voice interconnections throughout a land battle zone at least 100 km deep. The communication system also provides robust and seamless connectivity among ground, air, and naval elements of the coalition combat force dispersed over distances up to 200 km. Achieving this goal will require:

- Significant enhancement of tactical communications systems.
- Development of automated, seamless interfaces among tactical systems and between tactical and global communications systems.
- Development of sophisticated new radio and antenna systems for the airborne and ground OTM portion of the warfighting force.
- Evolution of theater/global broadcast systems as an integral element of seamless communications.
- Development of artificial intelligence tools for network planning, engineering, management, and operations.

To meet the FCS and Objective Force requirements for highly mobile, self-organizing, wireless, covert, and high-capacity multimedia information exchange to lower echelon maneuver forces, a number of programs have been initiated.

The Dynamic Readdressing and Management for Army 2010 (DRAMA) STO provides network management products to include protocols and algorithms needed to support mobility and allow the network manager the ability to manage highly mobile 100+ nodes.

The Free-Space Optical Communication System (FOCUS) STO will develop a new generation of short-range communications (Figure IV–10). This program will capitalize on the inherent covert attributes of laser and millimeter-wave (MMW) communications. The characteristics of extremely narrowbeam optical communications systems will be extremely advantageous to achieving the desired covertness. Tracking, signal acquisition and reacquisition, and networking technology will be developed.

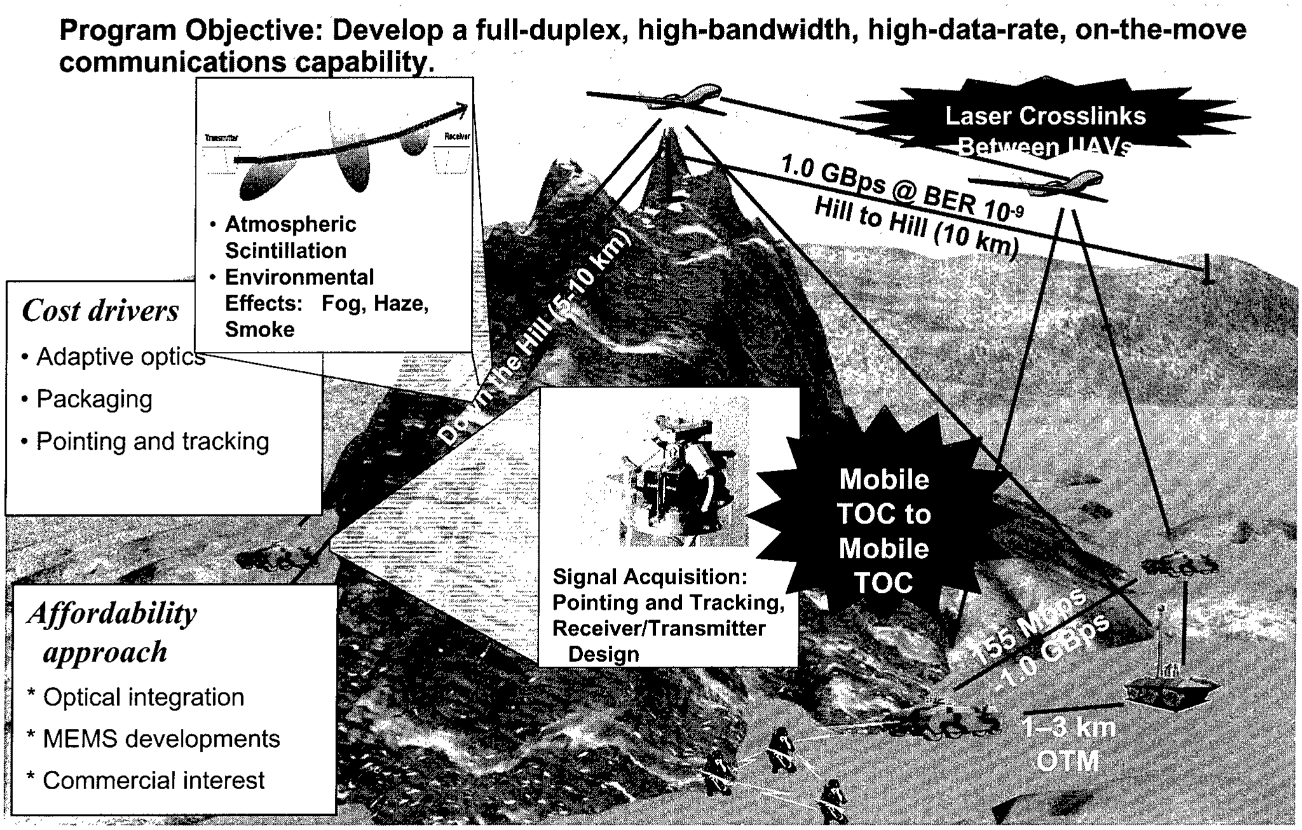


FIGURE IV–10. FREE-SPACE OPTICAL COMMUNICATIONS SYSTEM

The Information Dissemination Management (IDM)–Tactical program tailor's a DARPA/ Defense Information Systems Agency IDM to meet Army tactical needs to intelligently disseminate data directly to the warfighter's ABCS C^2 workstation. It provides the tools to dynamically tailor the information system to changing battlefield situations (ABCS and Maneuver Control System) and provides an information manager with functionality that extends the Global Broadcast Service broadcast manager to ABCS.

To combat the lack of frequency spectrum and limited bandwidth, the Smart Networked Radio Technology program emphasizes the tactical radio or what is commonly referred to as "Smart Networking." This amounts to the judicious use of bandwidth and power while maintaining an efficient data network commensurate with the throughput, delay, and connectivity needs of the users.

The Army Networking Technology program aims to develop the next generation of intelligent, survivable network control technology. It will be consistent with the Smart Networked Radio Technology and Tactical Information Assurance Technology programs by providing network control and management based on a model of the human thought process as well as the more traditional computation (Turing Machine) models.

The dismounted warrior will require a low-power, lightweight communications capability to ensure seamless connectivity with emerging military upper echelon communications systems and organic tactical sensors. The Army's Personal Communications for the Soldier STO program will assist in the definition and development of communications architectures at the battalion echelon and below in support of FCS initiatives. The objective is to develop the next-generation Land Warrior radio technology by leveraging DARPA small-unit operations Situation Awareness Systems and adapting commercial technology to support the needs of the dismounted soldier. The program will offer significant advantages in multipath performance (MOUT applications) and antijam/low-probability-of-detection (LPD) protection. This effort will eliminate the fixed cellular infrastructure requirements on which commercial cellular land network systems are based.

Challenges

Challenges in this area include:

- Communications mobility/wireless mobility issues (both nodes and base stations)
- Communications equipment interoperability in multivendor, multinetwork, joint/combined force, and commercial environments
- Protocols for high-data-rate subscriber loops subject to sporadic disturbances (e.g., Narrowband–Integrated Services Digital Network (N–ISDN) and Broadband–ISDN (B–ISDN) loops supporting OTM airborne, surface, and subsurface vehicles)
- Management of highly dynamic networks
- Integration of data and voice over low-bit-rate links
- Heavy multipath and deep fade effects
- End-to-end security
- Waveforms for low probability of interception (LPI) and LPD
- Development of conformal arrays for airborne and OTM antenna applications
- Wideband waveforms and network protocols for the software-programmable Joint Tactical Radio System (JTRS)
- Development of high-data-rate, highly directional datalinks
- Frequency agility.

Technology Objectives

Near-, mid-, and far-term objectives for Army C^4 are listed in Table IV–4. For clarity purposes, seamless communications is divided into five subareas: mobile networking, unattended sensor networking, information assurance, antennas, and secure personal communications.

TABLE IV–4. TECHNOLOGY OBJECTIVES FOR C^4

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Decisionmaking	Terrain, environmental, & event detection decision support software Automated flightplan guidance algorithms Embedded software tools to enable real-time collaborative planning in a 3D virtual environment Integrated & automated POS/NAV systems	Automated maintenance of a consistent, timely tactical picture in distributed C^3 system Automated situation awareness Demonstrate joint distributed collaborative planning & assessment tools with 3D visualization Automated cooperative interaction among three to four systems Robust precision POS/NAV	Robust cooperation Software agents dynamically support collaborative planning & execution Dynamic immersive rehearsal planning & execution environment Autonomous navigation in well-characterized terrain Adaptive tactical navigation
Seamless Communications—Mobile Networking	End-to-end quality of service Develop/demonstrate new phased array for wideband OTM operations Demonstrate network self-organizing & routing protocols Develop new airborne relay communications payload	Fully networked, self-organizing OTM wireless for 15–20 nodes 9.6-kbps MILSTAR, 5-Mbps wideband Bandwidth management Adaptive network protocols for mobility Short-range wireless Medium-range wireless Range extension Demonstrate media access control layer protocol Develop microcomponents & common architecture for microsensor processing First-generation self-healing	Fully networked, self-organizing, self-healing, OTM wireless for hundreds of nodes 9.6-kbps MILSTAR, 5-Mbps wideband Bandwidth management Adaptive network protocols for mobility Range extension 3D communications architecture Significant use of commercial satellites Spectrum agility Autonomous network planning
Seamless Communications—Unattended Sensor Networking	Fast acquisition <50 ms LPD/AJ Large breadboard Low-energy routing Self-forming adaptive 10-node network Integrated Meanderline antenna	Uses <120,000 mWh over 40 days Interradio range 200 m Radio to gateway 3 km Limited adaptive networking Security architecture with medium LPI/LPD/AJ 20-dB processing gain Radio size <6 cubic inches, 45 cubic inches with batteries Monolithic antenna	Provides FCS with remote access, reconfigure sensors & retrieve, & transmit sensor data while OTM Sensor-specific communications protocols, dynamic data routing algorithms, networking architecture, miniaturized RF components & antennas, power efficient components, OTM dispersal, & sensor architecture configured for survivability Demonstrate networked sensors & evaluate protocols Uses <80,000 mWh over 60 days Interradio range 400 m Radio to gateway 10 km Robust, self-forming, adaptive, 80-node network, scalable to 400 nodes with simulation Seamless security, adaptable LPI/LPD/AJ
Seamless Communications—Information Assurance	Access control Intrusion detection & response Security management M&S Attack/red team Test event—Electronic Proving Ground, Ft. Huachuca, AZ	Protect network 80% of the time ABCS/WIN protect Network access control—prevent malicious activity targets at computing & networking resources Intrusion detection & response Security management framework Internet attack simulation Security integration across tactical & sustaining base	Protect network 80% of the time Autonomous trusted agents Course of action analysis End-to-end encryption Multilevel security Self-detection of external attack Auto vulnerability assessment Security integration across tactical & sustaining base

TABLE IV–4. TECHNOLOGY OBJECTIVES FOR C^4 (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Seamless Communications—Antennas	JTRS at the halt multiband/OTM multiband SHF OTM positioner tracker—achieved EHF OTM positioner tracker—begin development JTRS OTM antenna—four approaches, prototypes to be tested Band-switched antenna—begin development Low-cost phased array—validate multilayered PWB & surface-mount production techniques Body-borne antenna—successful proof of concept	Increase message completion rate by 20% EHF SATCOM for communications between FCS & EHF satellite Ferroelectric/Ka-band PAAs OTM multiband antennas Altitude & heading reference system Reconfigurable OTM band switched Body borne First-generation vehicle conformal antennas	Increase message completion rate by 20% Ferroelectric/Ka-band PAAs VHF/UHF omnidirectional body-borne, low profile, & conformal Reconfigurable OTM band switched Smart antennas Micro antennas
Seamless Communications—Secure Personal Communication	Adaptable communications; functional breadboard evaluation in operational environment to support network speed of service & message completion rate requirements under dynamic mobility & hostile electronic warfare conditions for dismounted infantry	Provides FCS dismounted soldier with secure multiband personal communications with or without infrastructure Brassboard universal handset Wideband RF tunable front ends, reduced electronic signature, improved network availability, INFOSEC module, multipath protection	Provides FCS dismounted soldier with secure multiband personal communications, achieving low size, low weight, low power, and affordability Production-ready universal handset Low-power RF electronics; highly integrated, system-on-a-chip modem processing; improved, interference-resistant, software-programmable waveforms

E ELECTRONIC WARFARE

Electronic warfare (EW) is the capability to disrupt or degrade an enemy's defenses throughout the areas and times of conflicts and across the entire electronic, infrared (IR), and visual spectrums in order to enable the deployment and employment of U.S. and allied combat systems. EW includes capabilities for deceiving, disrupting, or destroying enemy surveillance, command and control, and weapon systems and sensors associated with the enemy's integrated air defense network.

EW includes any military action involving the use of electromagnetic (EM) energy to control the EM spectrum or to attack an enemy. EW is the leading technology for solving Army problems in scenarios where nonlethal (i.e., not permanent injury) force is required. EW also includes the critical capabilities of recognizing attempts by hostile forces to track or engage U.S. or friendly forces, automatically initiating the appropriate countermeasures or defense response and protecting friendly forces. As threat systems become more complex, the need to develop EW systems that can respond to changing environments is critical to achieving superior battlefield surveillance and survivability. Technology to collect, recognize, and process complex wave forms and provide effective jamming is essential. Knowledge-based systems using artificial intelligence and adaptive parallel distributed processing can provide "smart" software control to maintain an edge on a dense signal battlefield. Army EW modernization techniques, strategies, and programs will support the Army Vision, FCS, and Objective Brigade Combat Team initiatives. Each of these elements provides a range of benefits to Army EW modernization and can be executed in the absence of a greater C^2 warfare or information operations strategy.

Detailed descriptions of the EW subareas follow. Note that information on advanced technology development (6.3) EW systems is described in Section III–E, Intelligence, Surveillance, and Reconnaissance and Electronic Warfare.

Technology Subareas

The Army's EW applied research program has two technology subareas: Electronic Attack (EA)/ Area Protect (EP), and Electronic Support (ES).

ELECTRONIC WARFARE-RELATED STOs
Electronic Attack/Area Protect
Low-Cost EO/IR Countermeasures
Advanced Electronic Warfare Sensors
Advanced Radar Deception and Countermeasures
Compact Laser Sources for Infrared Countermeasures

1 Electronic Attack/Area Protect

EA involves the defensive or offensive protection of U.S. forces and platforms against hostile weapon, sensor, and C^3 systems. EA consists of a warning receiver to warn of impending weapon attack (attack warning), expendable countermeasures, and a jamming system working in concert to prevent sensor-guided weapons from hitting their target. The primary focus of EA is to provide the warfighter with the ability to detect, geolocate, identify, track, and classify threat and friendly systems; cue countermeasures; and classify potential threat and friendly sys-

tems at long range with high accuracy over the RF–IR–EO–UV spectrum. The new RF technology includes receivers, antennas and apertures, processors, sensor-fused algorithms, and signal analysis algorithms, all of which will help provide adequate time to respond with appropriate countermeasures.

EP supports the development of design features and employment techniques that provide U.S. forces accurate electronic sensors and systems, both offensive and defensive, in spite of hostile jamming, deception activity, and enemy weapon targeting. EP allows operational users to initiate and execute a mission without degradation from opposing EW, or from conventional directed-energy weapons cued or targeted by hositile sensors.

Goals

In the area of RF, EO, and IR electronic attack and electronic protection, the goals are to:

- Counter the integrated and network-centric radar, IR, and EO weapon systems.
- Increase the detection range over existing sensors by 100 percent.
- Improve angle-of-arrival determination to less than 1 degree.
- Enhance probability of detection (P_d) to over 95 percent, and reduce false alarms to less than one per hour.
- Meet specific goals established by the Army's EW vulnerability assessment (EWVA) program.

Future protection system designs use tradeoffs between active and passive protection. In addition, future deception and countermeasures must counter weapon systems that use multiple sensors in different bands to acquire, track, guide, and launch homing munitions. Jamming techniques, ultra-fast tuning modulators, and RF transmitter and IR laser sources will be developed that cover multiple bands. The next generation of communications jammers provides the warfighter the ability to intercept and bring under electronic attack advanced communication signals being used by adversarial C^2 networks on the digital battlefield. Electronic attack strategies devised and demonstrated during the Army's EWVA program will use prototype hardware and software to disrupt or deny the threat C^2 functions. In the near term, the goal is to demonstrate electronic attack against a set of digital formats being implemented in commercial communications and data transmission systems. The mid-term goal is to demonstrate the ability to disrupt networks and wide-bandwidth communications. The ability to surgically attack specific users by nonobtrusive means while maintaining the overall integrity of the targeted communications network is the ultimate long-term goal. The increasing use of common carrier commercial communications networks by potential adversaries presents the major technical challenge. It is essential to separate the threat-relevant communications from the purely commercial traffic and to perform effective EW without disrupting the entire network. These targeted communication systems are characterized as adaptive sophisticated digital networks and modulation schemes that employ various layers of protocol and user protection.

Challenges

The major technical challenges include the development of a high-accuracy subdegree direction-finding capability, which requires interferometric techniques, close-tolerance amplitude- and pulse-tracking RF receiver components, and low-signal-threshold detection. Development of functional elements using monolithic, microwave integrated circuits (MMICs) packaged into 1/30 of the current volume is the major technical challenge for an all-MMIC EW receiver. The complex task of assembling a digital RF receiver involves the development and integration of

high-speed, high-resolution digitizers and high-throughput digital processing for spectral analysis and dynamic range extension. Achieving real-time threat identification and location includes pulse-level specific emitter identification extraction, processing, and automation. To develop a highly stable RF receiver for detection and tracking of hostile emissions requires expanded processing bandwidth and dynamic range for environment characterization and extended frequency coverage.

The EO technology challenges include increasing sensor sensitivity and dynamic range, providing angle-of-arrival information for CM cueing, and increasing the detection bandwidth to encompass laser threats. Threat identification, off-axis detection, and automatic target recognition with jam-resistant software require component and processing improvements.

The EP challenge is to ensure that selected defenses do not degrade system, or system-of-systems, performance.

2 Electronic Support

ES is the EW element that gathers, consolidates, and employs information from hostile or potentially hostile electronic sensors and C^3 systems. ES is critical to developing a comprehensive picture of the battlespace and a reliable indication of hostile force movement and intentions. ES allows force avoidance, efficient engagement, and electronic deception of enemy sensors, weapons, and communications systems.

Goals

Near-term goals include the downsizing of today's bulky components to provide a rapidly deployable capability, and the conversion from special-purpose processors and software to a general-purpose suite. The intent is to provide the ability to specifically tailor and reprogram these systems quickly, either locally or remotely, to meet the current and changing threat. Mid-term goals include development of signal processing techniques that provide effective electronic support against common-carrier, multiple-access commercial communications in order to identify, locate, and exploit threat users. The long-term goal includes the continued development of adaptive multifunctional sensor technologies that can perform the ES mission intercept role while also reducing the parts count. This encompasses deception and jamming to counter the use of increasingly more complex communications systems and noncommunications threat emitters in both urban and non-urban terrains.

Challenges

As with electronic attack/area protect, the increasing use of common carrier commercial communications networks by potential adversaries presents a major technical challenge. This implies the need for advanced front-end receiver architectures and signal processing techniques capable of providing ES mission functions against increasingly complex signal modulation methods and structures coupled to higher data rates and user protection schemes.

Technology Objectives

Near-, mid-, and far-term objectives for Army electronic warfare are listed in the Table IV–5.

TABLE IV–5. TECHNOLOGY OBJECTIVES FOR ELECTRONIC WARFARE

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Electronic Attack/Area Protection	Improve broadband HF/VHF passive antenna efficiency by 10% E–J bands, precision angle of attack, polarization insensitive 120 × 120 uncooled two-color IR missile warner Intercepts correlated to a priori electronic order of battle (EOB) database; pop-up located to 4% of range in 10–20 s Reduce signal processing time by 33% Increase power efficiency by 25% Reduce processor size by 25% Jam K-band target tracker radar Jam advanced CAT 1 fuze, update CAT 2 ECM testbed	Improve antenna efficiency by >30% while reducing size by 90% A–K bands High-gain, high-power, ground-based antennas 256 × 256 uncooled two-color IR missile warner Intercepts correlated to a priori EOB database; pop-up located to 1% of range in 5–10 seconds Double the number of signals processed Demonstrate jamming source capable of defeating multispectral IR/EO/UV missile seekers Jam/deceive LPI & area surveillance radars and network-centric C^2 Jam CAT 2 fuzes	40% improvement in HTSC material operating conditions Integrated A–M bands, laser warning, EO/IR FPA 256 × 256 uncooled two-color IR missile warner Increase processing speed & computations per second by 50% Jam/deceive netted LPI, air defense, & area surveillance radars Jam CAT 3 and CAT 4 fuzes Deceive and jam network advanced centric C^2 and air defense systems
Electronic Support	Improve receiver dynamic range by 20% Demonstrate ESM capability against impulse radars Digital receiver to support lightweight UAV-capable ESM against tactical radios	Reduce receiver size by 50% Real-time access & exploitation of adversary nodes with stealth & real-time countermeasures against selected nodes Reconfigurable, lightweight, conformal antennas capable of precision direction finding for advanced communication UAV ESM for FCS targeting	8:1 reduction in receiver size & power requirement Real-time access & exploitation of 98% of adversary nodes with 98% stealth & real-time countermeasures against selected nodes Multifunctional, very high dynamic range & bandwidth digital receiver with signal storage for deception & jamming of communications

F GROUND COMBAT AND TACTICAL SYSTEMS

The Army focuses on ground vehicle technologies that provide our soldiers with the capabilities needed to dominate the maneuver war. The ground vehicle technology area incorporates efforts to support the basic Army and Marine Corps land combat functions: shoot, move, communicate, survive, and sustain.

One of the mounted forces' most critical deficiencies in the post–cold-war era is the inability to rapidly deploy forces for a range of worldwide missions. Current mounted forces are capable, but take too long to be deployed, have a large logistics tail, and are ill-suited to the third-world infrastructure. Current combat vehicles rely on traditional materials for construction, communications, training, passive armor protection against munitions, and conventional mobility.

A lighter force is required that can deploy overseas in less time, with fewer ships, and with reduced combat services support, and yet be equally lethal, survivable, and cost effective. Materiel, smart weapon, and survivability advances can lead to a fully air-deployable armored assault force or a more deployable heavy assault force requiring 50 percent or less of current logistics assets. Advanced ground vehicle technologies will enable increased use of air deployment.

Ground vehicle platforms require targeting, location, and acquisition systems capable of rapid detection, recognition, identification, handoff, or engagement of both ground and aerial targets beyond the threat detection range. Systems must perform effectively day or night in adverse weather, in cluttered background environments, and in the presence of countermeasures that include jamming and the use of low-observable and active defense systems. Ground vehicle platforms must execute at an improved maneuver tempo to optimize gains from digitizing the battlefield.

Through the integrated concept team and integrated idea team (IIT) processes, the user now has greater influence over S&T planning. The "system-level" programs that provide focus for many of the technology base programs are the FCS and Future Tactical Truck Systems (FTTS).

Technology Subareas

The Army's Ground Combat and Tactical Systems applied research program is structured around six technology subareas: Systems Integration, Vehicle Structures, Integrated Survivability, Mobility, Vehicle Electronics, and Robotics.

GROUND COMBAT AND TACTICAL SYSTEMS-RELATED STOs
Systems Integration
Combat Vehicle Concepts and Analysis
Concepts for 21st Century Truck-Based Tactical Vehicles
Integrated Survivability
Armament Decision Aids
Laser Protection for Ground Vehicle Vision Systems
Ballistic Protection for FCS
Mobility
Combat Hybrid Power Systems
Robotics
Semiautonomous Robotics for FCS

1 Systems Integration

This effort focuses on system integration of future systems in both the virtual and real environments. In the virtual environment, realistic, three-dimensional computer-generated concepts are developed and assessed using state-of-the-art modeling and simulation resources. In the real environment, robust technology demonstrations and system-level ATDs are developed to assess advanced concepts in a realistic, user-oriented environment. To facilitate the collaboration between government agencies and industry, this effort is also reaching the commercially developed Integrated Data Environments. The results of the efforts in the virtual and real environments help to refine requirements, drive technology goals, optimize designs, and maximize ground vehicle force effectiveness. Future systems as well as demonstrators are the realization of the Army and Marine Corps users' requirements and the opportunities harvested from the results of technology subsystem development programs, international agreements, and the commercial marketplace, as well as stimulating the need for new technology programs.

Goals

The primary goal of systems integration is to demonstrate lighter, more lethal, and more survivable ground combat and tactical vehicles. Four types of M&S will be employed: engineering models, constructive simulation, distributed simulation, and virtual reality prototyping. The analyses will span the entire vehicle combat spectrum and will be performed analytically, physically, and interactively using simulation methodologies. Concepts will mirror technology and can be readily evaluated for mobility, agility, survivability, lethality, and transportability. These form the basis for trade studies, validation, verification, and accreditation for an optimal technology mix. Working closely with the user, virtual systems will be converted to real-world ATDs that will yield maximum payoff. A system-level ATD is the Future Scout and Cavalry System (FSCS).

COMBAT VEHICLE CONCEPTS AND ANALYSIS STO (1998-02). This STO program will optimize the design of future vehicles in the virtual environment. This facilitates component and system development and refines user requirements such that the most operationally and cost-effective vehicles (new starts and modifications to existing systems) are provided to the Army. The mission of this program is to provide program planning, perform technology surveys and assessments, and conduct computer-based system, subsystem, and component concept design, integration, and analysis to meet future vehicle development. The products include computer-aided design (CAD) virtual prototypes with associated analysis, technology surveys and assessments, cost and operational effectiveness analysis, and program planning. The benefits include development of virtual prototyping vehicle geometry, assessment and refinement of user requirements, system-level guidance to the technology base, rapid exploration of multiple-vehicle options, and optimization of vehicles prior to detailed design.

CONCEPTS FOR 21ST CENTURY TRUCK-BASED TACTICAL VEHICLES STO (2000-03). This program will demonstrate, through virtual prototyping and M&S, the feasibility and operational potential of advanced commercial and military technologies with application to tactical vehicles. Some of the specific technologies to be explored include advanced crew stations incorporating seamless communication for improved control, embedded training and onboard mission rehearsal, lightweight advanced structure, enhanced vehicle survivability through integral and modular armor combined with advanced hit avoidance and signature management, advanced propulsion technology, advanced active suspension and wheel technology, and robotic enhancement of

mission-critical tasks. These technologies represent state-of-the-art advances in the areas of survivability, mobility, transportability, supportability, communications, and training.

Challenges

To provide the user with systems that can attain an effective balance between enhanced fighting capability, survivability, and deployability, while meeting or exceeding operational effectiveness, cost, manufacturing, and reliability and maintainability goals.

2 Vehicle Structures

Ground combat system application technologies will be developed to optimize and exploit the structural integrity, durability, ballistic resistance, repairability, and signature characteristics of a vehicle chassis and turret fabricated primarily from composite or titanium (Ti)-based materials. Current ATD vehicle chassis efforts center on the development of vehicles composed of advanced lightweight materials to demonstrate this approach for new lighter vehicles.

Goals

Goals are to develop composite, Ti-based, and other lightweight materials to make FCS lighter and more deployable (33 percent lighter in the structure and armor combined), versatile (multiple combat and support roles), and survivable (better ballistic protection and reduced signature).

Challenges

Use of composite materials or Ti as the primary structure in the combat vehicle chassis is new. Composite issues include durability, producibility, and repairability. Titanium has limited use on combat vehicles because of cost.

3 Integrated Survivability

Integrated survivability technology will protect ground combat systems from a proliferation of advanced threats. With ever-changing threats and missions, the integrated survivability approach allows flexibility in meeting mission needs. Detection avoidance, hit avoidance, and kill avoidance technologies will be developed and integrated to enhance overall vehicle survivability.

Detection avoidance technologies include signature management and visual perception. Signature management efforts are focused on exploring vehicle signatures in the visual, thermal, radar, acoustic, and seismic areas and in various atmospheric conditions. Visual signature analysis will be enhanced with visual models and laboratory experimentation of visual perception.

Hit avoidance provides a lightweight approach to defeating smart and precision-guided munitions. Hit avoidance technologies include EW and active protection. EW sensors and countermeasures are integrated in ground vehicles through the commander's decision aid (CDA) to provide protection without burdening the crew. The CDA with sensor information locates, tracks, validates, and prioritizes the threats, subsequently managing an optimal automatic or semiautomatic countermeasure response to neutralize the threat. It also provides the capability for modular integration of sensors and countermeasures to meet mission requirements. This system can be tailored to the vehicle and threat with the advantages of horizontal technology integration. The CDA may provide a cue for the Active Protection System (APS), which tracks, intercepts, and

physically defeats large-caliber threats at a range sufficiently distant from the defended vehicle to ensure its survival.

Kill avoidance technologies include the development of armor, laser protection work, and exploration of non-ozone-depleting substances to use for fire suppression. Armor plays a synergistic role with detection and hit avoidance on the modern battlefield. It provides the last line of defense. By 2003, FCS armors with areal densities of 160 lb/ft^2 (frontal) and 20 lb/ft^2 (side) will be demonstrated. By 2005, FCS armors with areal densities of 80 lb/ft^2 (frontal) and <20 lb/ft^2 (side) will be demonstrated. Laser protection technologies are being developed to prevent blinding and eye damage of vehicle crews from battlefield lasers, including "agile-wavelength" laser threats. The work in this area is twofold. First, nonlinear optical materials developed commercially and at other DoD agencies will be characterized. Second, work to design and integrate a retrofit optical surveillance system is being performed. Advanced protection includes the exploration of non-ozone-depleting substances for fire suppression use. This work will focus on demonstrating environmentally and toxicological acceptable replacements for Halon 1301 in fire suppression systems in crew-occupied compartments of ground combat systems.

Goals

The goals of this subarea are to integrate individual technologies into a cohesive, supportable, and affordable package for application to ground crew vehicles; synthesize a universal kill mechanism capable of defeating a full spectrum of munitions, including kinetic-energy and chemical-energy rounds; develop a precision timing concept for the proximity fuze used to activate the kill mechanism; develop a cost-effective APS sensor; develop robust APS detection and tracking hardware; and integrate armors and structures to significantly improve the space and weight efficiency of future vehicle protection.

ARMAMENT DECISION AIDS STO (1997-01). This STO effort will enhance the capability of the mounted warfighter and commander to fight, win, and survive on the digitized battlefield by providing full-spectrum decision aids to support rapid terrain analysis, situational awareness/common operational picture, mission/engagement planning, self-defense, sustainment, data management, and analysis for direct- and indirect-fire applications. In FY01, the program will demonstrate a full suite of reusable and adaptable armament decision aid components and supporting software process and repositor technology to reduce workload, mission response time, and software cost. A robust voice or natural language operator interface capability will be demonstrated that is functional with 99 percent reliability in a high-noise (120 dB) vehicle environment. *Transitions to:* PEO–GCSS, PM–Crusader.

LASER PROTECTION FOR GROUND VEHICLE VISION SYSTEMS STO (1997-01). This effort will build and test a demonstrator of a new, retrofittable, wide-angle optical viewing system incorporating advanced laser protection materials. These new optical systems could replace the current vision blocks found in combat vehicles allowing the soldier to view the battlefield while protected from eye-damaging laser energy, including frequency-agile laser weapons.

BALLISTIC PROTECTION FOR FUTURE COMBAT SYSTEMS STO (2000-06). This STO program will develop and test armor systems that address the ground platform needs of the Objective Force, its enhancements, and FCS for protected firepower and survivable mounted infantry. It will build on lightweight armor systems developed under the Future Light Vehicle Ballistic Protection Technology STO, using advanced materials, and improve the mass efficiency of the armors produced under that STO.

Challenges

The cost of the currently identified technologies is prohibitive for application to all vehicles; however, synergistic effects result through application to specific classes of vehicles. The integrated survivability approach ensures the proper mix of these technologies so that survivability and mission flexibility may be achieved.

The major challenge is to develop a compact missile that integrates miniature navigational inertial measurement unit (IMU) devices, maintains high KE with increased velocity, and provides a nondetonable, high-performance, reduced-signature propellant.

4 Mobility

The Army has unique performance requirements (e.g., high-speed cross-country mobility) and operational constraints (e.g., engine cooling under armor, thermal signature control) that are not developed commercially. Mobility components for ground vehicles include the suspension, track, wheels, engine, and transmission (conventional and electric drive). While contributing to both the survivability and the lethality of ground combat systems, mobility technology strives for doubling the cross-country speed of combat vehicles. Vehicle cross-country speed is usually limited by the driver's ability to tolerate the vibration and shock energy transmitted through the suspension. Electronic controls have greatly enhanced our capability to actively control damping rates of the semiactive suspension systems and the force actuation of active suspension systems, thereby allowing greater speeds and improved platform stability.

Most combat vehicles (except the tank) use commercially modified diesel engines at or above their commercial power ratings. Current commercial diesel engines do not have sufficient power density for combat vehicles and must be modified to meet ever-increasing mobility and ancillary power requirements.

Goals

Early activities will determine the engine configuration and advance the technologies for high-power density diesel engines. Technology developments will focus on the areas of turbomachinery, fuel injection and combustion, thermal management, and cold start. By 2010, a complete propulsion system with a commercial derivative diesel engine could be developed that has a power density of 5-sprocket horsepower per cubic foot (versus 3.3 for the M1 Abrams).

The Combat Vehicle Mobility Technology TD (1997–03) effort will result in a demonstration of a track tensioner, nitrile track, and 15-kW motor drive inverter (FY01); and formulation of FCS engine concepts and development approaches. By FY03, the electric combat vehicle technology will be demonstrated on a testbed.

COMBAT HYBRID POWER SYSTEMS STO (2000-04). The CHPS program will transition technology from the DARPA CHPS program in FY00 and configure the CHPS architecture to the next planned Army combat vehicle (FCS, Objective Force vehicle). TARDEC will then build, integrate and operate a system integration laboratory (SIL) version of this CHPS configured to the next planned Army combat vehicle. The SIL will have real propulsion motors, flywheel and battery energy storage, advanced engine, advanced SiC motor controller/inverter, pulsed forming network for directed-energy weapons, and EM armor.

Challenges

Future electric-hybrid ground combat systems require the capability to operate power electronic devices at elevated temperatures. This is critical for achieving the volumetric goals desired for the Army's vehicle systems. A high-power density, low-heat rejection engine is also a challenge. For advanced track systems, the major challenge is to develop lightweight tracks while maintaining track durability. Rubberband tracks must be developed to move beyond lightweight applications into the medium-to-heavyweight vehicles. A challenge for enhanced fuels and lubricants are the higher engine operating temperatures that are to be expected in new systems. Enhanced petroleum, oil, and lubricants (POL) must provide for better fuel economy and ensure systems are protected at these higher temperatures.

5 Vehicle Electronics

This technology subarea strives toward developing a standardized framework to seamlessly integrate vehicle electronic subsystems and develop advanced soldier–machine interfaces. This will enable current and future ground vehicles with a reduced crews and crew load. Intra-vehicular electronics provides the necessary integration flexibility to support the wide-ranging battlefield digitization functionality over the next decade. It is the first step toward creating a general-purpose sensor fusion electronic platform for multipurpose sensors.

Goals

The goals of this subarea are to develop advanced multirole crew stations with individual "vehicle transition ready" components, including intelligent driving decision aids, decision aids, automated route planning, embedded mission rehearsal:

- Perform 100 percent of fight (19K), scout (19D), and carrier (11M) crew tasks with additional tasks of controlling UAVs and UGVs performed with two crew members.
- Demonstrate 1,000-Hz control loop.
- Demonstrate live-virtual simulation of vehicle in training exercises.
- Achieve 500,000 source line of code software reuse.

Challenges

Technical challenges include reducing the number of crew and timelines required to to perform all required tasks; developing reconfigurable crew stations equally capable for execution fight, scout, and carrier roles; and reducing the training requirements for multimission stations.

6 Robotics

This technology will be found in a wide array of future military systems, including UAVs, UGVs, and unattended ground sensors. The technology will provide future forces with increased operational reach (e.g., using intelligent assistants to enhance operator functions, create uninhabited wingman vehicles for manned systems); enhanced survivability (e.g., removing human operators from weapon systems to reduce armor requirement, vehicle size, and signature); and increased deployability (e.g., reduced overall weight and volume due to less armor, lower logistics requirements resulting from smaller system size and volume).

These activities may be accomplished through telepresence or teleoperation, autonomously, or semiautonomously (i.e., under "high-level" control by human operators). In abstract terms, robotic systems must sense the environment and characterize it in a meaningful, iconic fashion

(i.e., a knowledge database that includes contextual information), from which a plan (or control law) can be formulated and executed to impact that environment (e.g., control an actuator) in order to meet some goal. The underpinning technologies that will contribute to the advancement of robotics include perception, intelligent control, man–machine interface, advanced locomotion, and manipulation.

Perception is the ability of a system to autonomously "comprehend" its environment. It includes examining how environmental parameters (e.g., lighting, contrast) influence perception algorithms, the limitations imposed upon various classes and types of sensors by missions or desired system behaviors, and the intelligent fusion or preprocessing of sensory information that provides cues and enhances understanding of the local environment. Intelligent control emphasizes flexible control systems combining reflective and reactive behaviors enabling autonomous systems to conduct complex tactical operations in dynamic environments with limited supervision. Control architectures must be capable of decomposing tasks, plans, entities, and events into manageable units, developing a systematic framework for addressing and prioritizing them, and possessing sufficient flexibility to rapidly adapt to changing environments, including graceful degradation when partially damaged.

Advanced locomotion technology will enable unmanned systems to maneuver through terrain currently traversable by manned systems or, in the case of smaller systems, terrain traversable by dismounted soldiers or perhaps terrain that currently neither can easily traverse. It must focus not only on multiple forms of mobility, including wheeled and tracked vehicles that might be found in current-generation manned systems, but also on legged, articulated, climbing, or hopping locomotion, or hybrids combining multiple modes of locomotion.

Goals

Technology efforts are directed at developing algorithms for real-time object and terrain detection, classification, and ultimately identification. The use of both passive (machine vision in both visible and IR wavelengths) and active (laser scanners, laser radar, and radar) sensor technology is being pursued. Multispectral and sensor fusion techniques are being employed for object and terrain classification. Near-term efforts are aimed at reducing the perceptual requirements of unmanned systems by relying on a manned lead vehicle to "proof" terrain for following unmanned systems, taking advantage of human sensing and reasoning to reduce the burden on the unmanned systems.

SEMIAUTONOMOUS ROBOTICS FOR FUTURE COMBAT SYSTEMS STO (2002-04). This program will develop autonomous mobility technology critical for future Army Objective Force systems, including unmanned elements of FCS and crew aids for manned systems. The principal focus is on robotic elements that maneuver in high-hazard environments forward of manned systems. This program will combine robotic functionality with human capabilities to provide flexible, semiautonomous control modes for FCS elements. The program goals include demonstration of semiautonomous cross-country mobility at speeds of up to 35 mph (day)/20 mph (night), baseline adaptive tactical behaviors employing learning algorithms, and robust mobility reducing the frequency and duration of operator intervention.

Challenges

The key challenges to semiautonomous mobility or perception (specifically the identification of both positive and negative obstacles, including those hidden by vegetation, that would inhibit

the mobility of the unmanned system) are inadequate intelligent planning of movement to accomplish military mission, the need to reproduce the tactical maneuvers and behaviors employed by manned systems, and the soldier–machine interface required to control and coordinate the unmanned systems.

Technology Objectives

Technology objectives are shown in Table IV–6.

TABLE IV–6. TECHNOLOGY OBJECTIVES FOR GROUND COMBAT AND TACTICAL SYSTEMS

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Systems Integration	Develop & analyze tactical vehicle, FSCS, & FCS concepts Downselect FSCS lethality option with P_k = 1 at 50% increased engagement range Transition innovative FCS concepts to FCS industry teams & Objective Force IIT	Develop optimized FCS concepts & structured concepts process Transition FTTS concepts & analysis to industry	Demonstrate in the field a combat vehicle with 40% increase in cross-country speed, 20% increase in fuel economy, 50% increase in survivability, & 33% lighter, reduced GVW of platforms
Vehicle Structures	Complete 6,000-mile endurance experiment	Develop & demonstrate a vehicle chassis & turret to meet FCS 20-ton GVW requirement	Develop vehicle chassis & turret to support advanced systems
Integrated Survivability	Demonstrate improved Abrams frontal armor with 35% weight reduction Demonstrate a 25% increase in missile lethality with novel penetrators, miniaturized high-g guidance & control components, & fully navigational IMUs	Demonstrate side ballistic panels with 75% reduction in detectability Demonstrate FCS frontal armor with areal density of 80 lb/ft^2 Demonstrate FCS side armor with areal density of <20 lb/ft^2 Demonstrate APS to defeat KE & high-explosive antitank threats	Integrate FCS armor Apply integrated armor/APS to a vehicle
Mobility	Demonstrate semiactive suspension on Bradley fighting vehicle that will yield a 30% mobility improvement Determine active suspension requirement for heavy tracked vehicles	Demonstrate M2 Bradley track that will reduce vehicle signature by 30–50% with a 23% track weight reduction Demonstrate heavy vehicle band track with a 300% track pad life improvement Demonstrate high-temperature SiC switches to support electric drive Demonstrate 50% decrease in obstacle marking effort Reduce bridge system weight by 50%	Demonstrate fully active electromechanical suspension on a >20-ton tracked vehicle Develop & demonstrate a combat vehicle power pack
Vehicle Electronics	Develop the crew interface & vehicle architecture for the FCS program Demonstrate off-road driving using indirect vision at 100% direct vision rate Develop semiautonomous driving, route planning, & embedded simulation technologies	Demonstrate 100% of fight (19K), scout (19D), & carrier (11M) crew tasks with additional tasks of controlling UAVs & UGVs performed with two crew members Increase the architecture performance of combat vehicles 10X Develop mission planning & rehearsal technologies & cognitive decision aids Demonstrate embedded battlefield visualization on a moving vehicle testbed	Develop crew interface suites for vehicles that will lead to a seamless interface with the digital battlefield
Robotics	Follower vehicles demonstrating: • 30-kph onroad, 15-kph offroad—GPS breadcrumb operation • Limited on-board perception—decision capability—human intervention for exceptions • Up to 1 hour or 50/500 m separation • Avoids large intervening obstacles	Follower vehicles demonstrating: • 100-kph onroad, 15-kph offroad • Improved perception enables 24-hour or 1 m –200 km separation • Operator Intervention for rare exceptions only	Removal of dependency on lead manned system to achieve performance Demonstrate: • 100-kph onroad, 65-kph offroad • Operator intervention for rare exceptions only

G WEAPONS

The Weapons technology area includes efforts devoted to armament and munition technologies for all new and upgraded nonnuclear weapon systems. The efforts in this area are directed toward providing demonstrated technology that better enables the warfighter to incapacitate or destroy enemy personnel, materiel, and infrastructure. A major challenge is to provide over-matching lethality in Objective Force platforms that are much smaller and lighter than current ground combat systems.

The weapon technology area strongly supports the needs of the Army in both tactical and strategic mission areas. It responds to the Army's operational needs for cost-effective system upgrades and next-generation systems in support of Future Combat Systems and the Objective Force. Performance objectives focus on projecting precision lethal or less-than-lethal force against an enemy with minimal friendly casualties and collateral damage. General objectives address the need for affordable, all-weather, day and night precision strike capability against critical mobile and fixed targets from effective standoff distances; gun and missile systems for advanced, lightweight air or land combat vehicles and vehicle self-defense systems; lightweight, high-performance gun and missile systems for artillery applications; weapon systems to disrupt enemy mobility and information infrastructure; precision lethal force projection; and air and missile defense (AMD).

All of the technologies described herein will enable weapons and munitions to be more affordable and smaller or lighter (thus addressing their logistics burden) while maintaining or increasing their lethal effects. These technologies will provide lightweight armament systems enabling lethal lightweight ground combat vehicles; novel KE penetrators and missiles for defeat of advanced explosive reactive armors; low-cost, advanced self-destruct and safe and arm fuzing; precision, extended-range, multifunctional munitions; crew-served weapons that will enhance the fighting capabilities and survivability of dismounted battlefield personnel; and alternative defeat mechanisms for advanced artillery, mortars, area denial, and armor systems to enable FCS and the Objective Force, as well as to provide upgrade opportunities for fielded combat systems.

Technology Subareas

The Weapons program is structured around seven technology subareas: Guidance and Control (G&C), Guns—Conventional and Electric, Missiles, Ordnance, Weapon Lethality/Vulnerability (L/V), Radio Frequency (RF) Directed-Energy Weapons (DEWs), and Air and Missile Defense.

WEAPONS-RELATED STOs
Guidance and Control
Advanced Sensors for Smart Munitions
ATR for Weapons
MEMS-Based Angular Rate Sensors
Guns (Conventional and Electric)
EM Gun Technology
Light Fighter Lethality
Missiles
Compact Kinetic-Energy Missile Technology
Flexible Sustainer for Multimission Weapons
Loitering Attack Munition—Aviation
Deep Throttling Booster
Point-Hit Multiple Launch Rocket System
Ordnance
120-mm Extended-Range Mortar Cartridge
Target Destruct
RF DEW
Agile Target Effect(s) Systems for the Battlefield
Air and Missile Defense
Solid-State Heat Capacity Laser (SSHCL)

1 Guidance and Control

Guidance and control of conventional weapons is the application of sensors, computational capability, and specific force generation that allows a weapon to engage both fixed and moving targets with improved accuracy and lethality while minimizing collateral damage and casualties. A key effort in this subarea is the ATR for Weapons STO.

AUTOMATIC TARGET RECOGNITION (ATR) FOR WEAPONS STO. This program will extend the range of conventional weapon systems through various technology approaches in order to facilitate a more favorable loss-exchange ratio on the battlefield. It will provide for effective weapon engagement against a widely dispersed threat within the context of the digital battlefield, and demonstrate extended-range capabilities for lock-on after launch (LOAL), which will play a crucial role in future soldier/weapon platform survivability. This LOAL fire-and-forget capability will benefit the reacquisition of targets after loss of lock and optimize the aimpoint selection for increased warhead effectiveness. The goal by FY01 is to use collected data in flight simulations and performance assessments for applicability to relevant weapon systems.

Goals

Goals include:

- Demonstrate a microelectromechanical systems (MEMS) 1-deg/hr gyroscope and a 1.0 milli-g accelerometer.
- Demonstrate a miniature guidance inertial measurement unit (IMU).
- Develop ATR for LOAL fire-and-forget at extended ranges.
- Develop and test cost-effective, jam-resistant, precision guidance package.

- Develop a rugged, dual-axis MEMS-based angular roll sensor on a single substrate and a continuous roll rate measurement with reverse roll capability.
- Develop open systems technology for a common fire control system that includes developing and testing target acquisition and guidance system technology for multiple mission roles, developing common mechanical and electrical launcher interfaces, and integrating and demonstrating subsystems into a universal plug-and-fight modular firing system.

Challenges

G&C technologies involving guidance information and signal processing, inertial sensors and control systems, and missile system sensors and seekers present major technical challenges: precision guidance of small-diameter weapons; enhanced target acquisition, including masked target detection; operational performance measures for multispectral missile seekers; and proprietary architectures that limit fire control system versatility. Responding to these challenges will require the infusion of a number of emerging technologies that are not currently in the G&C program. The G&C program is coordinated with the technical objectives in the manufacturing technology (ManTech) program to achieve manufacturing and producibility goals; extensive use of simulation is made to reduce overall R&D costs.

2 Guns—Conventional and Electric

This subarea develops both conventional and electric gun technologies for all new and upgraded gun systems (small arms, mortars, air platforms, and lightweight ground combat vehicles). It includes efforts directed toward future "generic" applied research and system technologies for small, medium, and large calibers, including barrel/launcher, ammunition/projectile, power supply and conditioning, weapon mechanism/ammunition feeder, propellants/ignition systems, and fire control.

Goals

Goals include:

- Demonstrate integrated multirole armament system for FCS providing lethality overmatch capability for closed and tactical deep fight.
- Demonstrate compact EM armament.
- Demonstrate Responsive Accurate Mission Module employing a mortar armament in a mission module designed to be integrated into the Robotic Follower ATD to provide mobile indirect fire system capabilities for FCS.
- Demonstrate Objective Crew-Served Weapon (OCSW) as an effective replacement for MK19/M2/M240 machine guns in dismounted and secondary armament roles.
- Define, develop, and demonstrate Light Fighter Lethality, a lightweight weapon technology incorporating miniature, course correcting, mini-guidance/seeker projectiles with near 100 percent lethality, while having common system architecture (individual, crew, personal, mission specific).
- Demonstrate Advanced Medium Machine Gun, a lighter, more effective system providing increased maneuverability and portability, permitting long-range, sustained, high-volume, lethal, and suppressive fire, as replacement for light and selected medium machine guns.

Challenges

The major challenges are improving hit probability and lethality on target, extending the maximum range, reducing the weight of the total system, ensuring all-weather operation, and reduc-

ing barrel wear. Advances in composites, new propellants, and sophisticated electronics hold promise of overcoming many of these challenges.

3 Missiles

This subarea develops rockets, missiles, and propellants for antiair and antisurface warfare. It includes efforts directed specifically toward material process techniques; analytical design tools; and adaptable, minimum smoke, insensitive propellants, and associated motors and engines for rockets and missiles. A key STO in this subarea is the CKEM Technology.

Goals

Goals include:

- Demonstrate beyond-line-of-sight (BLOS) Networked Fires Weapon (NetFires), including the Precision Attack Missile (20–30 km) and the Loitering Attack Missile (100 km with 30–45-minute loiter).
- Demonstrate components of gel propulsion and pintle-controlled solid propulsion that provide thrust flexibility and meet the insensitive munitions requirement in low-cost, compact packages.
- Demonstrate an integrated system for design of tube-launched missiles capable of remotely monitoring the environments experienced by missiles to determine out-of-spec conditions and to quantify remaining useful life in plastic encapsulated microcircuits, solder joints, and propellants while the assets are deployed, in storage, or being transported.
- Demonstrate a modular missile payload (Javelin) mounted on an HMMWV-based robotic system.
- Demonstrate a prototype, low-cost, compact, expendable UAV.
- Demonstrate a 48-inch, 50-pound hypervelocity KE missile.

COMPACT KINETIC-ENERGY MISSILE (CKEM) TECHNOLOGY STO. This program will develop and demonstrate advanced hypervelocity missile technology necessary for the next-generation KE weapon applicable to the FCS. CKEM will demonstrate enhanced system lethality with a 4-foot/ 50-pound hypervelocity KE missile and miniature guidance IMU technology. By FY01, the program will demonstrate a 25 percent increase in missile lethality and conduct government-industry operational environment component demonstrations. By FY02, critical technologies applicable to FCS will be demonstrated and then validated through the use of battlefield Simulation Modeling for Acquisition, Requirements, and Training (SMART).

Challenges

The major challenge is to provide affordable performance optimized and matched to a broad range of targets and intercept conditions, while maintaining or reducing the weight and size of the warhead or rocket. Specific challenges include design of fuel-efficient, lightweight, low-cost turbine engine and inducted and air-augmented rockets of controllable thrust; nondetonable, high-performance, reduced signature propellants; and miniaturization and integration of system components.

4 Ordnance

The Ordnance subarea develops munitions, projectiles, fuzes, explosives, and novel concepts for conventional warheads and penetrators for antiair and antisurface warfare. It includes efforts directed specifically toward advanced warhead and penetrator concepts, advanced kill mechanisms employing multioption warheads, new warhead materials, advanced gun propellants,

material processing techniques, analytical design tools, advanced explosives, advanced sensors, signal processing algorithms, guidance integrated fuzing, miniaturized solid-state components, countermeasure resistance, electronic safe and arm, reliability, and affordability. The Target Destruct STO relates to this subarea.

Goals

Goals include:

- Develop and demonstrate a 120-mm cargo-carrying mortar cartridge having significantly greater range capability and lethal effectiveness than current round.
- Demonstrate a suite of companion ammunition for FCS Multirole Armament System, including advanced KE round (0–4 km), a multipurpose extended-range munition (2–12 km), and smart cargo round (4–50 km).
- Develop and demonstrate air-bursting munitions in medium-caliber cannon systems for 30–40-mm Advanced Light Armament for Combat Vehicles.
- Develop and demonstrate a hard kill mechanism for an Active Protection System (APS) to enhance survivability of high-value assets (e.g., light and heavy armored vehicles, command stations, ships) by intercepting and destroying the incoming threats.
- Demonstrate a common aperture laser radar (LADAR)/IR transducer for current smart submunitions to improve countermeasure performance, provide target classification capability, decrease false alarm rates, and increase overall systems effectiveness.
- Demonstrate more powerful explosives (MPEs) incorporating nanomaterials and novel ingredients.
- Develop and demonstrate insensitive, high-energy, electrothermal–chemical (ETC) propellant for the FCS Multirole Armament System.

Challenges

The major challenge is to provide affordable performance optimized and matched to a broad range of targets and intercept conditions, while maintaining or reducing the weight and size of the munition, warhead, or rocket. Promising materials such as tantalum, molybdenum, and tungsten may provide dramatic improvements in warhead lethality. Innovative warhead concepts need to be developed that can be optimized to defeat more than one target type. Higher performance requires more compact, novel lethal mechanisms to both KE and CE as well as higher energy density insensitive explosives. Innovative warhead concepts need to be developed that can be optimized to defeat more than one target type. Higher performance requires more compact novel lethal mechanisms for both KE and CE, as well as higher energy density insensitive explosive formulations. Other challenges include development of novel warhead concepts (GEN II/colinear explosively formed penetrator and compact shaped-charge); development and integration of selectable and multimode warhead technology, and exploitation of advances in liner materials and more powerful, less sensitive explosives; demonstration of MPE for precision warhead that will generate higher energy levels and reduced sensitivity characteristics; and integration of guidance, navigation, and control technologies for effective design of cost-effective precision munitions.

5 Weapon Lethality/Vulnerability

Weapon L/V refers to the science of understanding the mechanisms by which a warhead, penetrator, or other ballistic mechanism can defeat a target. Vulnerability, a characteristic of a target, describes the effects of various damage mechanisms to the physical components of the target

and the resulting dysfunction. Lethality, normally used from the perspective of the attacking weapon, includes the ability of the weapon to inflict the damage mechanisms upon the target as well as the effects of those mechanisms (target vulnerability). This subarea addresses the tools, methods, databases, and supporting technologies (e.g., solid geometric modeling tools, modern coding environments, supportive hardware configurations) needed to assess the L/V of all U.S. weapon systems, including aspects of design, effectiveness, and survivability (Figure IV–11).

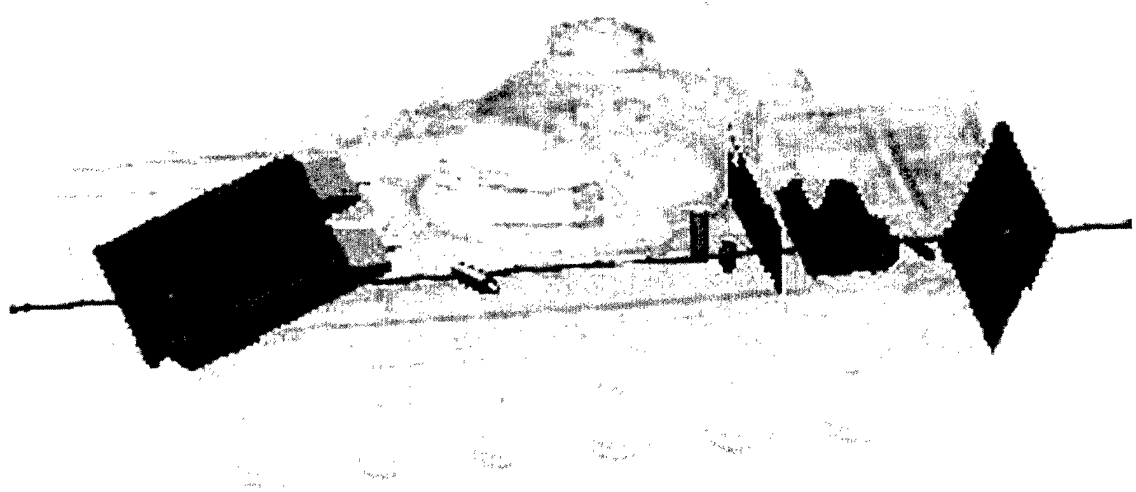


FIGURE IV–11. PHYSICS-BASED METHODOLOGY TO ASSESS FCS LETHALITY/VULNERABILITY

Goals

Goals include:

- Develop algorithms to predict effectiveness and vulnerability of APSs.
- Develop and validate methodology to predict penetration by hypervelocity weapons.
- Demonstrate first-order shock propagation model for HE blast loading.
- Develop and validate methodology to predict blast and acceleration effects on air and ground platforms and crew.

Challenges

The greatest challenge is to assess the L/V of U.S. systems at the earliest possible stage in the weapon development or upgrade cycle, when inexpensive changes can lead to large increases in the survivability of crew and performance. To complicate matters, new defeat mechanisms (e.g., hypervelocity missiles, top-attack systems, tactical ballistic missiles) must be modeled against an increasing list of sophisticated targets with new materials and novel armor designs. Other challenges include developing first-generation models to predict terminal effects on composite materials; characterizing fragment and debris clouds behind armors, accounting for all fragment parameters (e.g., mass, speed, shape, spatial distribution); and determining sensitivity of modern electrical subsystems and other components to ballistic blast and shock.

6 Radio Frequency Directed-Energy Weapons

The RF DEWs subarea develops DEW source, pulse power, and antenna technologies with a tunable target effects capability for future Army systems.

Goals

Goals include:

- Demonstrate interference modulation high-power microwave source concept for use in susceptibility testing and field tests.
- Develop RF DEW hardening for monolithic microwave integrated circuits (MMICs) used in Army systems.
- Develop high-gain, broadband antennas.
- Develop and demonstrate SiC hardening devices and use of chaos theory research results to achieve greater control of RF DEW sources.

Challenges

Global technical issues include the need to develop high-power RF generators that are smaller, lighter, and more fuel efficient. In addition, projected targets require intensive susceptibility studies to determine the best attack methods. Other major technical challenges include development of improved modulators, RF sources, and antennas; enhanced radiation beam control to reduce size, weight, and power requirements; new and improved electromagnetic hardening devices and techniques; and nonlethal control with significant standoff range.

7 Air and Missile Defense

AMD encompasses all defensive measures designed to destroy attacking enemy aircraft or to nullify or reduce the effectiveness of such an attack. As the Army transforms into an Objective Force, the AMD force will continue to execute AMD missions on the battlefields of the future while supporting the Army's transformation. To be successful in this mission, the air defense artillery will focus on the concepts of the Army's vision for transformation while maintaining the capability for full-spectrum dominance. The AMD force will maintain an affordable capabilities-based force to execute missions in support of the national security strategy.

Defeating the wide range of future threats will require an AMD force more lethal than its adversaries. The challenge is to transform the AMD force into a lethal force that will meet the AMD operational goal—nothing targets or attacks the force from the air.

The Army's AMD applied research program is structured around directed-energy lasers. This area is dedicated to technologies that relate to the production and projection of a beam of intense EM energy or atomic/subatomic particles that are used as a weapon. DEWs will provide dramatic improvements in current weapon capabilities and enable new missions that are not currently possible. The SSHCL STO is key to this subarea.

SOLID-STATE HEAT CAPACITY LASER (SSHCL) STO. This program will develop lightweight, pulsed-laser technology for a variety of air and missile defense missions. The SSHCL beam is generated from neodymium-doped crystal slabs, which are pumped by monolithic, high-duty-cycle, high-existence diode arrays. Supporting technologies have been demonstrated. The primary issues are in heat management and reduction of the costs of producing the laser diodes. The goal is to

develop and demonstrate a three-disk-module SSHCL by FY04 and to develop and deliver SSHCL modules for a weapon-scalable prototype by FY07.

Goals

The goal is to develop a lightweight, pulsed laser technology that will provide a solid-state heat capacity laser for a variety of short-range, time-critical AMD missions.

Challenges

The primary challenges in developing a solid-state heat capacity laser for AMD operations are:

- Current solid-state lasers have not produced the high average power required for AMD operations.
- A heat management system that will remove waste heat from laser crystals needs to be developed.
- Flashlamp repetition rate is too low for AMD operations.

Technology Objectives

Technology objectives for the Weapons area are shown in Table IV–7.

TABLE IV–7. TECHNOLOGY OBJECTIVES FOR WEAPONS

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Guidance & Control	Demonstrate a stable airframe with 90% reduction in guidance section spin rate Demonstrate dual-axis MEMS-based angular rate sensors Test precision guidance package	Develop solid-state/photonic components that reduce the cost of G&C systems by 3X Demonstrate improved fuel gels and high-burn exponent solid propellant Demonstrate low-cost MEMS-based IMU	Automate G&C software generation reducing acquisition cost by >10% Exploit multisensor target/scene simulation to reduce T&E costs by 30% Develop advanced hardware & software code sign techniques
Guns—Conventional & Electric	Demonstrate OCSW prototype with a weight of <38 lb Demonstrate fire out of the battery with integrated ETC ignition showing precise control of recoil mass & ignition timing, & 60% reduction in recoil trunion force	Demonstrate a 30% increase in Abrams direct-fire system accuracy with a 300% increase in P_h at 3 km Demonstrate propellant compatible with ETC ignition with sensitivity equivalent to JA2 Demonstrate integrated ETC multirole, lightweight armament that provides robust defeat of threat spectrum in "red zone" & tactical deep engagements (0–50 km)	Demonstrate propellant specifically tailored to ETC ignition with sensitivity less than JA2 Demonstrate large-caliber EM gun with pulsed-power energy density of 10 J/g, launcher life of 100 rounds, & launch package parasitic mass of 40%
Missiles	Demonstrate a tactical air-breathing missile with a 3X–4X increase in range Demonstrate low-signature gel motor Demonstrate remote monitoring system for tube-launched missiles Complete flexible long-range datalink design Improve turbojet/turbofan engines Complete designs to adapt Loitering Attack Missile (LAM) for rotary-wing launch Demonstrate a 25% increase in missile lethality with novel penetrators, miniaturized high-g guidance & control components, & fully navigational IMUs	Flight test a 35- to 40-kg compact KE missile Demonstrate turndown ratios of 10–20:1 with a >90% efficiency Demonstrate Precision Attack Missile (PAM) in NetFires Weapon using controllable-thrust pintel motor, uncooled imaging IR seeker, & semiactive laser (20–30 km) Demonstrate LAM in NetFires Weapon using turbojet engine & LADAR seeker (100 km with 30–45-minutes loiter time) Demonstrate in-flight test of compact KE missile	Double rocket payload & range without changing weight or volume Extend propulsion system shelf life to >25 years

TABLE IV–7. TECHNOLOGY OBJECTIVES FOR WEAPONS (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Ordnance	Show 25% increase in performance for explosives Demonstrate algorithms to direct & fuze aimable warheads	Demonstrate a tactical subprojectile for the advanced KE warhead that meets aerodynamic & terminal requirements Use new energetic filters & binders, new recrystallization, coatings processes, & novel nanopowder technology to produce higher performance but less sensitive explosives Demonstrate compact/multiple-effects warheads Demonstrate advanced KE round with penetration capability 70% greater than M829A2 at 4 km Demonstrate multipurpose extended-range munition with LOS/NLOS lethality from 2–12 km against spectrum of threats Captive flight test of LADAR sensor for smart submunition with 0.33-km^2 footprint, P_d >0.9, P_c >0.75, Dfa <0.15 Demonstrate aimpoint selection via neural net Demonstrate strapdown MMW seeker that can acquire & track in a real-time laboratory test	Reduce emissions from explosives production processing & demilling by 90% Develop warheads that are one-half the diameter of current warheads with twice the lethality Demonstrate smart cargo round with BLOS/NLOS lethality from 4–50 km
Weapon Lethality/ Vulnerability	Develop first-generation models to predict & analyze penetration of emerging composite materials Develop model for stochastic analysis of fragment effects Upgrade L/V models to enhance wargame fidelity of the DISN	Develop & validate methodology to predict penetration by hypervelocity (400–1,400 m/s) weapons Improve body-to-body impact models for tactical ballistic missile targets Demonstrate first-order shock propagation model for HE blast loading	Decrease software preparation time by 5X, improve fidelity by 2X, reduce LCCs of conventional weapons by 2X Incorporate large-scale hypervelocity penetration mechanics of geological & layered structural materials Develop fire/thermal & toxic fume transport model
Radio Frequency Directed-Energy Weapons	Demonstrate high-power interference modulation source concept Develop multibeam klystron Develop RF DEW modulator	Demonstrate SiC hardening devices Demonstrate high-average-power TWTs Demonstrate advanced RF DEW pulsers	Demonstrate techniques for hardening against upset Demonstrate high-power wideband amplifiers Demonstrate advanced conventional source systems Demonstrate alternate source weapon systems
Air & Missile Defense	Demonstrate a 15-kW diode-pumped solid-state laser Develop SSL architecture design Demonstrate single module cooling	Demonstrate a 100-kW diode-pumped solid-state laser Develop 15-kW breadboard & demonstrate short pulse length & high repetition rate Develop 100-kW prototype solid-state heat capacity laser	Field prototype laser weapon system Acquire laser weapon system Demonstrate 100-kW solid-state heat capacity laser

H SOLDIER AND PERSONNEL TECHNOLOGIES

Highly trained soldiers ready to accomplish the diverse missions of the 21st century are the backbone of America's Army. Advanced high-technology weapons, sophisticated information systems, and digitized equipment do not win wars or keep the peace. Trained and ready men and women on the ground—the human operators of our systems—do.

The key to force lethality, survivability, and unit efficiency is the effective use of human resources. Soldier and Personnel Technologies provide capabilities and methods to ensure that the military's most critical resource—its people—are properly selected, trained, and equipped to perform effectively and as safely as possible.

Advances in Soldier and Personnel Technologies are essential for the Army to meet global commitments in combat and peacekeeping roles. The Soldier and Personnel Technologies area takes a unique, multidisciplinary approach to the human role in combat operations. The capability to collectively draw on the physical, biological, biomedical, and behavioral sciences plus human factors engineering is needed more than ever. Instead of facing a single massive threat, the warfighter is challenged by the potential for simultaneous, multiple, low-intensity conflicts. This change in operational backdrop has compelled a corresponding change within the Army, where the focus has shifted from a force with new and larger weapon systems with increased speed, range, and firepower to a smaller force with fewer weapon systems but with more functionality. Other changes include fewer hands-on training hours, fewer people, less acquisition, and aging systems that must be maintained. This change in focus places a growing critical demand on the soldier, who is "in the loop" of every weapon system.

Through vigorous application of soldier systems technologies to current and future weapon systems, the Army can achieve 33 percent reductions in average crew size; 25 percent reductions in physical, perceptual, and cognitive workload; doubling critical decisionmaking accuracy and reliability; 20 percent or more reduction in the weight of personal equipment; 15 percent increase in locomotor performance; 30 percent weight reduction in improved ballistic protection; and 50 percent reduction in total life-cycle cost (LCC).

Technology Subareas

The Army's Soldier and Personnel Technologies applied research program is structured around four technology subareas: Information Display and Performance Enhancement (ID&PE), Design Integration and Supportability (DI&S), Warrior Protection and Sustainment (WP&S), and Personnel Performance and Training (PP&T).

SOLDIER AND PERSONNEL TECHNOLOGIES-RELATED STOs
Information Display & Performance Enhancement
Cognitive Engineering of the Digital Battlefield
Design Integration & Supportability
Warrior Systems Modeling Technology
Warrior Protection & Sustainment
Multifunctional Fabric System
Ballistic Protection for Improved Individual Survivability
Lightweight Soldier
Load Carriage Optimization for Enhanced Warfighter Performance
Conducting Nanocomposites and Nanofibers for Warrior Systems
Personnel Performance & Training
Computer-Generated Forces
Intervehicle Embedded Simulation Technology
Simulation-Based Aviator Training
New Assessment Techniques to Maximize 21st Century NCO Performance
Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal
Advanced Tactical Engagement Simulations
Training Tools for Collaborative Web-Based Environments
Advanced Trauma Patient Simulator

1 Information Display and Performance Enhancement

ID&PE technologies support future needs in data visualization and situational understanding, aural and visual interface, immersive interface, intelligent aiding and decision support, decision-centered staff process control, supervisory control and teleoperation, and physical aiding. ID&PE technologies seek to enhance the processing and delivery of task-critical information to individuals and groups and to aid the functional operation and logistical support of weapon and information systems.

Goals

The ID&PE subarea goals are aimed toward enhancing soldier capabilities for both cognitive-perceptual and physical-physiological task demands. For the near term, in both cases, the first tactic is to lower requirements through human-friendly design of interfaces, tasks, and equipment.

To capitalize on the soldier's cognitive capability and flexibility, information must be presented in an easily grasped form to the operator of any system, especially during combat. Technologies emerging in ID&PE address the presentation (visual, aural, and force feedback) of intelligent aiding and decision support information. Advances in display, information management, and decision support technologies offer significant potential for enhancing the interface between the warfighter and future weapon systems. For the mid to far term, full-time, real-time situation awareness is the core challenge for cognitive S&T research.

A data visualization effort confronts the data overload problem for cross-service applications spanning command centers, vehicle crew members, and individual combatants. It exploits com-

puter graphics, voice control and sound cues, better display symbology, and stereo 3D displays. Aural and visual interface research develops information management criteria for advanced component technology to maximize the information throughput and minimize the likelihood of operator overload in either the visual or the auditory processing channel. It focuses on uses of aural and visual cues to present spatial information for (1) integrated flight, weapon, and sensor operations across the range of aircraft, ships, command centers, helicopters, and tanks; and (2) the individual warfighter.

Challenges

Challenges in the ID&PE subarea include presenting information (visual, aural, haptic) to the warfighter using innovative displays that remain "friendly" even under combat stress conditions. New ways to represent and visualize information extracted from complex data domains are essential. How to use multimodal control and input methods such as touch, speech, eye tracking, and natural language requires a significant S&T effort.

A second challenge is to extend the soldier's physical, cognitive, and psychological capabilities. This involves a core human factors task—that of merging and extending existing models of biodynamics and ergonomics with emerging models of human cognition, individual and organizational decisionmaking, and combat stress reduction.

2 Design Integration and Supportability

DI&S technologies support the fielding of affordable, effective equipment needed for future military operations by advancing the state of the art in soldier system design tools, performance requirements estimation, performance metrics, soldier system integration, logistics readiness, and sustainment logistics.

The application of effective DI&S technologies will be key toward meeting warfighters' needs for weapon systems and equipment that are affordable, supportable, user friendly, and designed from the warrior-as-user perspective. Personnel and maintenance costs are major contributors to LCCs of modern combat systems. Cost can be controlled by optimizing individual system performance through the integration of soldier capabilities and limitations into the design of the system, and by reducing logistics.

Goals

Design integration and supportability goals include (1) designing tools for physical accommodation, (2) devising methods for human error assessment, (3) developing metrics and tools for assessing soldier performance in relation to mission effectiveness, (4) demonstrating how to achieve effective crew system integration during design, and (5) developing tools to both streamline and enhance the weapon system support infrastructure at both retail and wholesale levels. All of the design integration tools are set in the context of the Army's Manpower and Personnel Integration (MANPRINT) Program.

DI&S science and technology has two interrelated areas: design integration and supportability. Within the design integration area, the design tools program provides design technology building blocks for soldier–system designs across service applications. The crew–system integration program explores mission-unique integration concepts for specific platforms, missions, tactics, and operating procedures.

Within the supportability area, the readiness and sustainment logistics program focuses on field, depot, and pipeline-oriented supportability, especially maintenance performance, technical data, logistics planning, and asset distribution tools.

Challenges

The increasing complexity of emerging technologies is taxing soldier capabilities. Pertinent data from many disciplines (physiological, psychological, human factors, medical, etc.) need to be identified, integrated and applied. Methods need to be developed to extrapolate human performance data collected for lower complexity and slower performing systems to high-performance, highly complex multifunctional systems. Lastly, the development and application of new, more sensitive diagnostic metrics are needed to accurately gauge system-of-systems performance.

3 Warrior Protection and Sustainment

WP&S technologies support warfighting and peacekeeping mission capabilities through full-spectrum personal protection; troop sustainment, including rations and field feeding equipment; survival and rescue; advanced airdrop; load carriage optimization; and dismounted and mounted warrior systems integration, including warfighter systems analysis.

WP&S focuses on protecting and sustaining the individual soldier by providing food, combat clothing, and airdrop. (These three major WP&S areas are illustrated in Figure IV–12.) These efforts provide advances in nanotechnology, materials science, physics, applied mathematics, and chemistry that lead to significant reduction in soldier system weight, volume, power, and cost; advances in individual ballistic protection; countermeasures to sensors; laser eye protection; multifunctional materials; and individual and small-unit design and analysis tools.

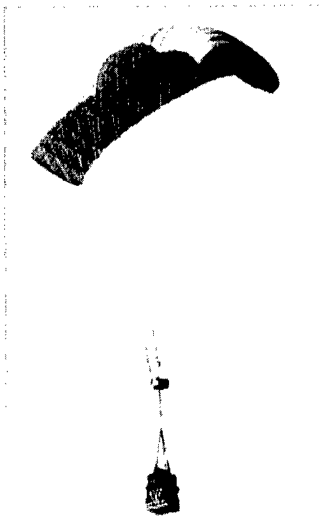
Technological efforts to sustain and enhance warfighter performance and combat effectiveness include (1) maintaining a current anthropometric database to ensure that the range of human size and shape variation is available for equipment and clothing design, nutritional performance enhancement, food preservation, packaging, and food service equipment and energy technologies; and (2) providing advanced and precision cargo airdrop systems.

Goals

The WP&S subarea goal is to enable warfighters (dismounted or vehicle crews) to function effectively and fully exploit weapon system capabilities despite battlefield, operational, and environmental hazards and enemy threats; they must be able to survive when the weapon system ceases to function.

Protection-related goals include development of high-performance fibers and materials that can automatically respond to threat stimuli, nonlinear optical materials, nanotechnology, individual equipment, environmental control systems, human physiology and biomedical effects, and human susceptibility to mechanical forces. Technologies address comprehensive protection against lasers, thermal threats, flechettes, small arms, and fragmentation and blast threats from mines and bursting munitions. Virtual prototyping tools are being developed to integrate warrior system technology concepts on the human form, and analyze form, fit, function (fightability) prior to breadboard prototyping.

Sustainment-related R&D addresses (1) nutritional bioavailability; food, texture, and structure optimization; acceptability quantification; nutrition–performance relationships; packaging; pres-



Airdrop: Precision airdrop will provide future warriors with "just-in-time" resupply of combat-essential food, fuel, ammunition, and medical supplies.

Combat Feeding: Nutritious field rations sustain and enhance warfighter performance and combat effectiveness.

Clothing: Land Warrior is the basic platform for technology development and insertion, including the future Lightweight Soldier and the MOUT programs. Potential technology insertions include wireless weapons interface, full-time links to battlefield assets, CB sensors, signature management, power sources and management, physiological monitoring, combat identification, advanced ballistics protection, and significant weight reductions.

FIGURE IV–12. WARRIOR PROTECTION AND SUSTAINMENT AREAS

ervation; stabilization; and process effectiveness validation; (2) combustion, heat transfer, thermoelectric power generation, automatic control, and refrigeration technologies; (3) designs and concepts for parachutes and gliding wings and cargo airdrop systems; and (4) theoretical and computational prediction and experimental determination of decelerator behavior and performance.

Challenges

The challenges of the WP&S subarea are to provide advanced technologies to protect and sustain warfighters and enable them to operate more effectively, with reduced signature, while withstanding environmental hazards (heat, cold, wind, and blast), combat threats (ballistic munitions, sensors, battlefield lasers), and secondary hazards (battlefield fires). A fundamental challenge is to develop and integrate advanced multifunctional protective materials with a focus on

materials that provide automatic responses to threat stimuli, while simultaneously reducing the overall system weight and bulk associated with increased multithreat protection. Additionally, integrated protective clothing and individual equipment challenges include development of cost-effective uniform materials that provide protection against multiple threats without imposing a heat-stress penalty. Improved methods of individual load-carriage design are challenged by the absence of detailed biomechanical data. The countersurveillance challenge is to provide passive protection against advanced multispectral sensors with emphasis on thermal signature reduction. The laser eye protection challenge includes the development of frequency-agile nonlinear materials that exhibit low switching thresholds and high third-order nonlinearities and that can be integrated into both day and night combat operations.

The Army vision will require greater strategic mobility and continued reliance on airborne insertion for forced- and early-entry missions. Reduction of jump-related casualties negatively impacting combat effectiveness, increased precision, and reduced vulnerability and detectability are key to the future. In order to achieve this, the challenges include low-cost sensor technology and manufacturing costs for developing a static line parachutist automatic activation capability; modeling transient parachute-opening processes; developing lower-cost gliding parachutes; advancing nonparachute decelerator technologies for soft landing of personnel and sensitive equipment; and developing high-glide decelerators for precision airdrop applications. Future challenges in aerial delivery include high-altitude insertion of individuals and small units with the ability to accurately reach drop zones from increased standoff distances during night and limited visibility conditions.

The challenge to providing mobile field services for kitchens, sanitation, laundries, and space heating is the efficient cogeneration of heat and electric power by integrating fuel cells and thermophotovoltaic generators.

Ration development challenges include effectively applying innovative food formulations, processing, and packaging to produce fresh-like ration components that can be used worldwide under all environmental conditions and to enhance soldier mental and physical performance through nutritional tailoring.

4 Personnel Performance and Training

PP&T research and development provides the scientific basis for selecting, assigning, retaining, and cost-effectively training quality soldiers; maximizing human potential; and maintaining readiness now and for the future. PP&T technologies support the operation and maintenance of both current and future systems and lead to increased readiness of warfighting forces. This is accomplished by strengthening unit readiness and reducing costs through advances in force management and modeling, selection and classification, human resource and leader development simulation-based training, training strategies, and training efficiency.

In the Objective Force of the future, relatively junior leaders will be faced with a much broader scope of responsibilities than has been the case in the past. Companies may be deployed on their own, and company commanders will therefore need to be able to command on their own. At all levels, the Army will need bold, innovative leaders who have the skills and ability to do things right. These leaders will need to be developed quickly, and behavioral science R&D addresses leader development programs. In addition, the Army must attract, select, assign, promote, and retain soldiers whose abilities and interests will fit the Objective Force's multifunctional job demands.

Behavioral science-based training R&D also addresses fundamental and applied problems seeking more efficient and effective training methods for the Army. This R&D will be driven by three broad categories of factors: (1) changes in Army materiel and doctrine, (2) changes in training policies and practices, and (3) introduction and expanded use of new training technologies. A key STO in this subarea is the Advanced Trauma Patient Simulation.

Goals

In the area of leadership, there is a need for new leader development technologies and leadership assessment devices congruent with rapid changes in the scope and nature of military operations. The Army must also develop new job-structuring methods to provide improved modeling of manpower requirements and personnel assignment; develop an improved model of human abilities to support the efficient, optimal assignment of personnel to jobs; expand measurement of human abilities to incorporate measurement of personality characteristics such as motivation, temperament, and values; and validate new test batteries to determine the predictive ability and utility of these new instruments.

The PP&T subarea will focus on developing simulation-based training technologies, including embedded training that realistically train warfighters in combat and support tasks that would otherwise be too costly, very difficult, or unsafe to train using operational equipment; maximizing and assessing the instructional capabilities of distributed interactive simulation (DIS) to effectively deliver distributed training to individuals and units; developing performance measures and feedback techniques to ensure that synthetic training environments will be used effectively for estimating and maintaining training readiness; providing cost-effective training strategies to maintain combat readiness via seamless combinations of virtual, constructive, and live simulation components; improving the efficiency of developing and delivering individual training to reduce the cost of military classroom instruction; and developing prototype intelligent tutoring systems in technically challenging military occupations for skill acquisition and sustainment.

TRAINING TOOLS FOR COLLABORATIVE WEB-BASED ENVIRONMENTS STO (2001–03). In cooperation with TRADOC, this STO combines efforts of STRICOM and ARI to introduce collaborative training into the Total Army Distance Learning Program. Eventually, it will enable education and training of forward-deployed FCS and combat service support units via internet technologies. These technologies will provide effective methods and procedures for the use of web-based, collaborative training environments, including a diverse array of support tools such as desktop videoteleconferencing, multiplayer game technologies, and asynchronous learning tools. It will create applications and tests of different training methods and procedures in a variety of scenarios, develop intelligent tutoring systems to provide the student "individualized" instructional support of cognitive training tasks, and develop virtual team members and virtual instructors—which allow for missing team members—supporting the "anytime–anywhere" training paradigm.

ADVANCED TRAUMA PATIENT SIMULATION STO (2001-03). This program develops a common medical modeling and simulation environment for initial, refresher, and sustainment training. The technology will analyze medical simulation and training requirements, design a methodology to support combat medical training, enhance triage, simulate treatment of patients, provide after-action review capabilities, and generate casualties and logistics supply data. The goal is to complete test, incorporate a medical simulator, and assess complete system interoperability by FY03.

Challenges

A major challenge is inferring what the future battle commander's critical thinking skills will need to be and how to acquire and improve those skills through instruction. A related challenge is providing assessment and support systems that help leaders become more flexible, adaptive, and effective in an era of accelerating change, volatility, digitization, information dominance, and speed.

Current approaches to job design and job structure are task-based, linking the required knowledge, skills, and personal attributes to specific tasks. This approach is enormously valuable, particularly for training purposes, but is limited as a basis for comparing and combining jobs, and for supporting selection, classification, recruiting, and career development. For example, R&D must focus on ways of capturing what future NCO jobs will demand in terms of individual attributes and skills, and what kinds of measures best predict which individuals should be selected for these new jobs.

Current approaches to selection tend to be cognitively based. Such approaches are supported by a long history of development and application. Noncognitive approaches are less established and more difficult to implement, but are necessary to identify future soldiers who have not only the ability to perform well but the motivation to succeed.

Approaches to attrition and recruiting have also suffered from a narrow perspective. Personal, organizational, economic, and social factors cannot be considered in isolation; rather, complex models are necessary that account for all of these factors and their interactions. Such models do not exist and need to be developed.

The Army needs to develop new training and performance measurement technologies that will allow it to train effectively for the full range of individual and unit tasks within budgetary constraints. Specific challenges include developing strategies for individual and collective training that can provide an effective and affordable mix of live exercises and synthetic training environments. A second challenge is assessing the capability of training aids, devices, simulators, and simulations with accompanying prototype training support packages, DISs, embedded training, and virtual environments (VEs) to support individual, unit collective, joint, and multinational training. A further challenge is demonstrating training strategies and performance evaluation technologies to support emerging digital technologies and the accompanying new doctrine. A final challenge is defining the relative merit of using simulators as the primary means of aviator skill proficiency training, in cost-effective combinations with aircraft, that exploit the training capabilities of both.

Technology Objectives

The Soldier and Personnel Technologies are objectives are shown in Table IV–8.

TABLE IV–8. TECHNOLOGY OBJECTIVES FOR SOLDIER AND PERSONNEL TECHNOLOGIES

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Information Display & Performance Enhancement	Develop context-sensitive intelligent interface Implement cognitive decision-aiding tools in simulation use Develop algorithms to support commanders for OTM operations Refine "audio icon" & integration in simulation platform Refine PNVGs Examine auditory vs. visual input benefits for dismounted HMD soldier Develop database of soldier clothing & equipment compatibility information Refine assessment techniques for national & international (joint coalition force) soldier modernization programs Develop prognostic model of intelligence production & fusion Develop "precursor/leading indicator" performance metrics & markers for individual, team, & unit	Develop indicators & warnings for dismounted soldiers Develop information engineering guidelines for information-rich environments Command OTM controls & layouts Develop "look-up" model linking compatibility issues with clothing, equipment features, ARL "obstacle" course performance times, & effects on related performance Develop instrumentation, data, & model to support improvement strategy for aiming accuracy, recoil mitigation, & indirect fire for small arms Examine strength augmentation & sensory enhancement links Develop performance-related model of fatigue/stress performance relationship For teleoperations, develop aids to provide textural & distance information, & to minimize attentional fixation	Multimodal interactive sensory displays 3D audio & video immersion displays 3D volumetric & immersion devices Human science design guide for HMD Integrate personal performance enhancement of hardware & weapons Fatigue/stress monitoring & feedback systems to synergistic human–system interaction
Design Integration & Supportability	Develop human resource cost models relative to IEW, C^4I Integrate models & databases for human facts, manpower, personnel, & trainning Develop task performance models for expanded mission areas (C^4I, maintenance, etc.) Evaluate alternative system designs at notional system stage Provide algorithms, data models, & vignettes to improve accuracy of combat assessments	Mission reconfigurable crew station Teleoperation crew station layout Simulation-based determination of training & system support concepts, requirements, & resources Database matrix for soldier system technologies for future system design evaluation HMPT analysis tradeoff tool for system redesign options Demonstrate a V&V model to evaluate combat worth of warrior systems	Integrated real-time & predictive system supportability & operational readiness assessment capability Full synergistic analysis capability from concept through prototype & from detailed interface specifications through force-on-force simulations Diagnostic links to system design, design costs, tactics, & training
Warrior Protection & Sustainment	Demonstrate blended fibers produced by spin lacing to create multifunctionalities Transition technology for novel multifunctional fabric system that reduces the cost of flame protection by 30–50% Establish models & performance criteria to predict & engineer appropriate levels of comfort/durability in the combat uniform system Transfer materials technology for an advanced bomb suit that provides equal protection at a 35% reduction in system weight Transition technologies into combat uniform systems that reduce the soldier's thermal signature Upgrade algorithms, data models, & vignettes that improve the range/accuracy of combat assessment by incorporating battlefield & restricted terrains as well as other environmental features Develop improved test methodology & assessment criteria to understand/ minimize behind-armor effects & to predict/validate material system ballistic performance Develop whole-body scan protocols compatible with ANSUR 2D database standard	Demonstrate multithreat (chemical protection, flame protection, clothing circuitry, camouflage) protection in electrospun fibers Optimize load-bearing systems for the human system (male & female) through the application of physiological/ biomechanical principles & material technology Transition warpaint that provides improved thermal reducing properties Provide a signature assessment for soldier systems transition technology for body conformal antennas Transition "power bus" technology for efficient power & data transmission in soldier systems Demonstrate virtual prototyping tools that combine 3D human motion capture, CAD translations of prototype warrior systems, & analysis of ergonomics & biomechanic effects Demonstrate wearable & lightweight (minimum 30% reduction) photovoltaic power devices & EMI shielding using nano-fiber-/nanoparticle-conducting composites Conduct 3D anthropometric database collection using a representative military population to augment existing anthropometric database	Develop advanced signature management techniques for combined visual, near/mid/ far IR, radar, & acoustical signature control Develop advanced multifunctional materials that provide full-spectrum protection to soldier systems Develop lighter weight future materials & system designs to protect against new higher velocity fragment threats & new/ emerging bullet threats to the head & torso Exploit nanotechnologies to optimize weight, protection, integration, & cost of soldier system components Transition the data collection methodology to military induction centers for real-time sizing & issue of individual clothing & equipment Integrate fuel cell & hydrogen-producing chemical heater with advanced shelf-stable foods in an autonomous meal preparation & serving system Develop interactive, highly functional components (smart foods) to provide enhanced delivery of physical & cognitive performance-enhancement constituents; integrate performance enhancing supplements with a personal status monitor; & develop ration selection module

TABLE IV–8. TECHNOLOGY OBJECTIVES FOR SOLDIER AND PERSONNEL TECHNOLOGIES (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
WP&S (continued)	Demonstrate experimental small- & medium-scale cogeneration systems based on thermoelectrics, fuel cells, & high-temperature liquid expansion Develop methodology to validate effects of targeted nutrient delivery Develop multifunctional packaging to remove/add components inside ration package to improve quality & acceptability Seek approval of antimicrobial materials for food packaging Demonstrate the application of pneumatic muscle technology as a soft lander system for heavy cargo reducing derigging times & as a low-cost control actuator in precision control of container delivery systems	Demonstrate compact, self-contained, self-heated meal module that automatically heats meals for remote site feeding, independent of a field kitchen Validate nonthermal preservation techniques to improve ration quality & reduce weight & volume Optimize the incorporation of complex carbohydrates for modulated energy release Improve barrier properties of packaging materials through nanotechnology Develop improved personnel armor casualty assessment model Demonstrate a long-range autonomous precision air delivery system with a 10,000-lb payload, 12–20-mile offset & 200-m CEP Demonstrate high-altitude, cost-effective precision resupply air delivery system with a 10,000-lb payload with a 200-m CEP Demonstrate advanced airdrop predictive performance & design optimization modeling & virtual testing that reduce development, testing, & procurement costs Demonstrate an integrated static line parachutist automatic activation capability Demonstrate technologies that reduce parachutist rate of descent to 0–8 ft/s Demonstrate novel integration manufacturing techniques, including nanotechnology, to reduce soldier system weight & power requirements Incorporate individual & small-unit tactical communications & individual navigation systems analytical technology into the HLA-compliant overall model Demonstrate 25–30% decrease in weight for protection against multiple (conventional/emerging) ballistic threats	Develop lightweight packaging materials that decrease visibility & allow logistics monitoring to ensure just-in-time delivery of sustainment Demonstrate extended delivery accuracy to 50-m CEP with 40–60-km offset for payloads up to 10,000 lb Transition advanced lightweight personnel armor technology Demonstrate full-scale concept for guided, autonomous, precision heavy airdrop of FCS payload Demonstrate autonomous personnel soft landing system for SBA missions Demonstrate precision aerial insertion of combat teams during night & limited visibility conditions Demonstrate analytical technology to evaluate combat worth of warrior system concepts in the Objective Force to include domestic as well as joint international combat scenarios, vignettes, environments, & material concepts Demonstrate advanced airdrop recovery/ stabilization technologies that reduce ground dispersion & personnel/equipment link-up times
Personnel Performance & Training	Identification of NCO job requirements Initial model linking frequency & duration of deployments with commitment & retention Prototype training methods/strategies to facilitate skill acquisition in a digital environment Model training programs using simulators as the primary means for aviator skill learning Measures to assess battle commanders' cognitive skill performance Methodologies for training & assessing small dismounted unit leader performance in VE Methods to enhance LW effectiveness Measures of situational awareness in MOUT Identification of new screening tools for recruiters & recruiting station commanders Identification of job & organizational factors influencing enlisted attrition	New assessment techniques for NCO selection, assignment, & development Embedded training & assessment for operator- & crew-level tasks in FCS Prototype performance evaluation methods to support emerging digital equipment & doctrine Aviation training strategy using low-cost alternatives to resource-intensive training Methods for improving the acquisition & use of cognitive skills needed for 21st century battle command Interactive, VE-based training & mission rehearsal techniques for soldiers & small units Training techniques & strategies for warfighters to attain mastery of critical tasks & skills in synthetic environments Evaluation of options for operational use of new recruiter & station commander assessment methods Model for predicting & managing enlisted attrition	Job-specific selection & assignment methods that ensure flexible & effective personnel/job matching Organization & job design/redesign methods that keep pace with changing missions & skill requirements Advanced warfighting training strategies for soldiers & units to achieve hyper-performance & thereby attain 21st century battlefield dominance Methods for developing commanders of a more diversified military force to respond effectively & rapidly to future mission requirements Multiservice, joint, & multinational training methods & measures of performance

I BIOMEDICAL

Individual service men and women are the most important and most vulnerable components of military systems and mission capabilities. Disease and nonbattle injury typically far outweigh battle-related injury as the greatest cause of casualties among military forces. Regional, life-threatening, or incapacitating disease epidemics both limit and constrain military deployment alternatives. Widespread sickness and injury are mission aborting; high casualty and death rates are warstoppers. U.S. military hardware and diverse and increasingly complex operational scenarios pose a variety of risks to service personnel that can adversely affect performance and health, while post-deployment health problems have an adverse impact on future capabilities.

The demands of future operations are challenging the Army to increase its operational pace and as a prerequisite, radically reduce all forms of in-theater support, to include medical support. To ensure success under these conditions, warfighters must be optimally fit and better able to withstand stressors (physical, mental, and environmental) of any contingency deployment across the full spectrum of operations in support of the commander in chief. If soldiers are injured in combat, early response and a continuum of critical care from first response through evacuation must be maintained. Biomedical S&T seeks to ensure success by (1) making soldiers more resistant to the full range of current and emerging threats to health and performance that they may encounter, (2) finding operationally compatible means to avoid health and performance threats when possible, and (3) providing the means to deliver quality medical care on a geographically dispersed battlefield with limited medical personnel and equipment. These goals will be achieved by exploiting biotechnology (including genomic information, protein structural analysis, and genetic and protein engineering) and rational design and selection principles to identify protective and therapeutic vaccine and drug candidates; exploiting multivariate databases of animal and human physiologic and performance information, and applying improved understanding and modeling of human physiological and cognitive responses to environmental and operational stresses; and adapting information systems, sensors, effectors/actuators, micro-analytic techniques, and signal processing technologies (among others) to the problem of miniaturizing and automating diagnostic and therapeutic devices.

A robust military biomedical applied research program is needed to adapt civilian products for military use and where feasible to develop technologies with limited commercial appeal. In contrast to civilian biomedical programs, the military biomedical S&T investment (1) focuses on preservation of military operational capabilities, as opposed to simply preserving health, (2) addresses health threats that either are uniquely associated with military operations or are rare in industrialized nations, and (3) addresses problems of healthcare delivery in occupational environments that are not typically encountered in nonmilitary settings. Additionally, military biomedical S&T differs from hardware modernization programs in that biomedical programs and products are regulated by the U.S. Food and Drug Administration (FDA).

Military medicine and its R&D component are concerned with three general threats. First are those based on biologically active molecules and molecular complexes that enter the body in small amounts and cause death or injury through highly specific biochemical interactions with cells and tissues. This threat group includes chemical and biological warfare agents, natural infectious diseases, and toxic chemical contaminants in the operational environment. R&D in this area leads to drugs, vaccines, diagnostics, protection and avoidance materials, and related products and information. Second are those threats based on inappropriate deposition of energy in the body, from enemy or friendly weapons, or from the operational environment. These

threats result in nonspecific, often violent injuries that initially are quite different from those associated with biologically active molecular insults. Energy-based threats include blunt and penetrating trauma, blast, burn, high pressure and decompression, hot and cold environments, noise and vibration, impact and jolt, and laser and microwave radiation. R&D in this area leads to life-sustaining treatment, exposure standards, guidance for protective equipment and training procedures, and related materiel and information. Third are threats associated with "stress"—a poorly understood medical concept generally associated with the nervous system—that contributes to operator error, demoralization, inattention, fragmented unit performance, and training ineffectiveness. Such threats include fatigue and sleep deprivation, combat exhaustion, cognitive overload, and family disruption. R&D in this area leads to pharmacologic performance sustainment, doctrine recommendations, and medically based selection and training procedures.

POTENTIAL PAYOFFS FROM MILITARY BIOMEDICAL RESEARCH

Rapid field diagnostics

Single-dose oral vaccines to prevent infectious disease

Receptor-targeted immunization

Catalytic scavenger for broad range of chemical agents

Ration supplements to enhance performance

Biosentinels to detect health hazards of complex chemical mixtures

Strategies for muscle and bone repair to accelerate and augment physical training without injury

Injectable hemostatic and neuroprotective agents

Miniature noninvasive medical sensors

Real-time soldier and unit effectiveness models

Compounds to sustain cognitive functions

Automated casualty detection and triage

Prediction of performance status from physiological signals

Acclimatization strategies to exploit extreme environments

New drugs to counter emerging drug-resistant disease organisms

Wound dressings to prevent blood loss and accelerate healing

Multiagent vaccine delivery platforms for protection against BW threats

Technology Subareas

The Army biomedical applied research program is divided into four technology subareas: Infectious Diseases of Military Importance, Medical Chemical and Biological Defense (MCBD), Military Operational Medicine, and Combat Casualty Care. Each subarea focuses on a specific category of threat to the health and performance of soldiers. The first three subareas emphasize the prevention of battle and nonbattle injury and disease, while the combat casualty care research program emphasizes far-forward treatment. All three prevention research programs provide both medical materiel (e.g., vaccines, drugs, applied medical systems) and biomedical information. Combat casualty care provides medical and surgical capabilities tailored to military medical needs for resuscitation, stabilization, evacuation, and treatment of all battle and nonbattle casualties.

Each technology subarea has objectives that respond to the national military strategy. Since 1982, the Army has been designated as the DoD Executive Agent and Congressional Lead Agency for the joint service infectious disease research program. The Army is also the DoD Executive Agent for the Food and Nutrition RDT&E program. The National Defense Act of Fiscal Year 1994 (Public Law 103–160) consolidated chemical and biological defense (CBD) programs, including both nonmedical and medical, under the management of the Office of the Secretary of Defense, with the Army serving as executive agent. The MCBD programs are discussed in this section; the nonmedical CBD programs are addressed in Section IV–J, "Chemical/Biological Defense."

Biotechnology and advanced information technologies are cross-cutting enablers that have been and will continue to be embedded in multiple biomedical technology subareas. Biotechnology, including applications of functional genomics, protein engineering, and gene expression, is

being exploited extensively for vaccine, drug, and diagnostic discovery and development in the infectious diseases and MCBD technology subareas. (Other nonmedical applications of biotechnology are addressed in Section IV–P, "Biotechnology.") Advanced information technologies are being exploited in both the military operational medicine and the combat casualty care technology subareas, including (1) novel uses of sensor technologies for physiological monitoring, (2) sensor fusion and algorithm development for biomedical knowledge-based health monitoring and decision support systems, and (3) integration of advanced computing and communications technologies for health support modeling and telemedicine applications.

BIOMEDICAL-RELATED STOS
Infectious Diseases of Military Importance
A Multistage, Multiantigen *Plasmodium falciparum* Malaria Vaccine
Prevention of Diarrheal Diseases
Nucleic Acid (DNA-Based) Vaccines To Prevent Dengue
Development of a New Standard Military Insect Repellent
Military Operational Medicine
Warfighter Physiological Status Monitoring
Optimization of Physical Performance
Laser Bioeffects and Treatment
Pharmacological Strategies To Enhance Mental Performance in Fatigued Soldiers
Injury Prevention and Restraint Technologies for Ground Vehicles and Helicopters
Fusion of Warfighter Performance, Environmental, and Physiologic Models
Optimization of Visual Performance with Optical and EO Systems and Materials
Performance Enhancement and Injury Prevention in Hot Environments
Innovative Strategies To Assess Health Risks from Environmental Exposure to Toxic Chemicals
Rapid Analysis of Food and Water for Chemical and Microbial Contaminants
Inhalation Injury and Toxicology Models
Head-Supported Mass: Warfighter Health and Performance
Combat Casualty Care
Hemorrhage Control
Blood Products
Optimal Parameters for the Battlefield Resuscitation of Combat Casualties

1 Infectious Diseases of Military Importance

Infectious disease pathogens of military interest include a variety of bacteria, parasitic microbes, and viruses that are not common in the United States and industrialized nations but are endemic in other less developed regions. Of major importance to the military are the parasitic disease malaria, the bacterial diseases responsible for diarrhea (i.e., caused by *Shigella*, enterotoxigenic *Escherichia coli*, and *Campylobacter*), and the viral disease dengue fever. The program also develops improved materiel for control of arthropod disease vectors and addresses a variety of other threats to mobilizing and deploying forces, including hepatitis, meningitis, viral encephalitis, hemorrhagic fevers, and infection with human immunodeficiency virus (HIV). Improved diagnostic capabilities are also pursued to enable rapid battlefield identification and management of diseases for which there are no current methods of protection (thus limiting the spread of disease to healthy troops).

Goals

The primary goal of the military infectious disease research program is to identify enabling vaccine and drug technologies to prevent incapacitating and lethal infectious diseases that pose a significant threat to operational effectiveness. Identification of effective treatments to reduce hospitalization time and rapidly return personnel to duty is a secondary goal. Within the area of prevention, specific objectives focus primarily on vaccines since predeployment vaccination provides the greatest assurance of protection with the least in-theater logistical burden. However, few vaccines are available at present. Until vaccines become available, program goals also include development of new preventive drugs or biological agents to address ongoing needs and the potential emergence of biological resistance to current and future drugs. Specific program goals include:

- Identify candidate antimalarial drugs for prevention and treatment of multidrug-resistant malaria.
- Provide surveillance of worldwide malaria drug resistance to provide guidance and direction for new drug development.
- Explore novel applications of existing drugs and new drugs to treat serious viral diseases.
- Develop new or improved candidate vaccines for protection against falciparum and vivax malarias.
- Prepare genetically altered live-attenuated vaccines to protect against the major causes of dysentery.
- Develop a miniaturized, portable diagnostic test platform for use by forward-deployed medical units, and incorporate capabilities for rapid, sensitive, and accurate diagnosis of specific infectious diseases.
- Discover, evaluate, and develop vaccines to prevent dengue, Hantavirus (Korean hemorrhagic fever), and scrub typhus.

Challenges

New infectious disease threats continue to emerge. It is estimated that one disease of potential military importance will be identified each year while diseases that previously could be treated successfully develop resistance to formerly effective drugs. Army-supported research must develop fundamental insight into the biology of the infectious organism and human response to infection. Drug and vaccine development requires the use of animal models of human infection to validate their efficacy. In many cases, such as malaria, the species of parasite that will infect laboratory animals is not the same as those afflicting humans. Furthermore, the manifestations of the disease in an animal model may not reflect those seen in human disease. Therefore, other correlates of disease, such as cell or tissue culture models, need to be developed and used. To obtain sufficient quantities of a pathogen for study, methods need to be developed to grow the agent. Additional technical challenges include:

- Predictive validity of animal and laboratory models.
- Incomplete knowledge of parasite biology and mechanisms of drug resistance.
- Improved targeting of drug discovery and design.
- Enhancing the immune response of the tissues that line the airway and gastrointestinal tract.
- Insufficient sensitivity of diagnostic assays to detect pathogens.

2 Medical Chemical and Biological Defense

The MCBD research program works to ensure the sustained effectiveness of U.S. armed forces operating in a CBW environment by the timely provision of medical countermeasures to CBW threats. This is accomplished by the use of prophylaxes (vaccines and pretreatment drugs), enhanced therapeutics (antisera and improved chemotherapeutics), and improved chemical and biological agent diagnostic capabilities. Improvements in these medical countermeasures will maximize operational capability and sustainability. Vaccines are generally the products of choice for countering BW agents, owing to their relative simplicity of use and the maximum protection that they provide. In contrast, pharmaceuticals are better suited to counter chemical warfare agent (CWA) threats because CWAs are much smaller in molecular size than biological warfare agents (BWAs). Because of their smaller size, CWAs do not bind tightly to antibodies nor do they induce a protective antibody response. Agents of interest include a variety of bacteria, viruses, and microbial and plant toxins that have been validated as BWA threats, as well as chemical nerve, vesicant, and blood agents.

Goals

Specific near- and mid-term program goals include:

- Explore concepts for next-generation vaccines for plague and anthrax.
- Explore surrogate markers of protection and evaluate new-generation antibiotics for efficacy against bacterial threat agents in animal models.
- Assess antiviral compounds for activity against orthopox viruses and filoviruses.
- Develop therapeutic drugs for toxin threat agents.
- Evaluate the efficacy of candidate vesicant countermeasure compounds in animal models.
- Develop and assess diagnostic assays for CWAs and bacterial and viral threat agents.
- Determine bioeffects of acute and long-term, low-level CWAs.
- Explore a multivalent equine encephalitis vaccine (VEE, WEE, EEE) and candidate multiagent vaccines.
- Assess a nucleic acid-based portable device for identification of BWAs in clinical specimens, and explore concepts for next-generation advanced diagnostics device.
- Develop and validate a transgenic animal model for production of recombinant enzyme-based chemical agent prophylaxis.
- Identify and characterize drug or vaccine candidates for prophylaxis or therapy of emerging bacterial, toxin, viral BW threats, and novel CWAs.

Challenges

The development of new vaccines and drugs for a particular chemical or biological threat agent requires both close examination of the threat agent to determine the toxicologic or pathogenic mechanisms of the agent or disease and the development of appropriate pharmacologic or vaccine strategies to counteract these mechanisms. Strategies for vaccine development must embrace new knowledge regarding the human immune system. This includes information about the stimulation of immunity, the preservation of immunological memory, and the regulation or modulation of immune functions, including enhancement and suppression. Similarly, new pharmacological products exploit new knowledge regarding biochemical and pathophysiological mechanisms associated with toxic cell death and organ failure.

New candidate vaccines and drugs must be both safe and efficacious. These criteria are required by the FDA. Ethically it is not possible to conduct tests of the efficacy of chemical agent prophylaxes or treatments in humans, nor can efficacy of vaccines for BWAs be evaluated in this manner. Extensive safety and immunogenicity studies, however, are conducted in these development programs. Although efficacy testing must be conducted in animal model systems, models do not currently exist for some of the CB agents. The use of existing animal models is also limited by the desire to minimize the use of animals in drug and vaccine development.

The ability to quickly identify exposure to specific CWA/BWA and infectious disease agents and rapidly treat soldiers is critical to maintaining the strength of the force as well as giving commanders the ability to provide specific protective measures to warfighters not yet exposed. The ability to diagnose infection immediately after exposure would be extremely helpful in determining whether a BWA attack has occurred and how many warfighters were exposed and thus in need of treatment.

Additional technical challenges include:

- Developing appropriate animal models to predict human safety and efficacy of medical countermeasures.
- Increasing genetic and biologic information applicable to medical countermeasures against threat agents.
- Developing pretreatments and antidotes that are quick-acting, long-acting, and easy to carry and use.
- Analyzing new vaccine delivery systems and multiagent vaccines.
- Synthesizing and demonstrating safety of reactive and catalytic protectants.
- Developing rapid, sensitive, and specific identification technologies and reagents.

3 Military Operational Medicine

Military operational medicine applied research develops solutions to ensure that U.S. military personnel can respond to requisite physical and mental demands with agility and versatility across the continuum of military operations.

The research program is designed to (1) define strategies to protect soldier performance from degradation produced by the stresses of deployment and continuous operations, injury from environmental extremes, and injury from materiel and system hazards; (2) guide safety and design criteria for future military systems; and (3) quantify performance criteria and soldier effectiveness to improve operational concepts and doctrine.

Goals

Specific program goals include:

- Define warfighter macronutrient needs under conditions of environmental stress, and explore use of nutritional supplementation to reduce stress-associated performance decrements.
- Identify genetic markers of heat injury susceptibility.
- Develop predictive algorithms and models of metabolic, physiological, and biomechanical effects and performance, addressing impacts of heat, cold, altitude, physical exertion, hydration, blunt trauma, spatial disorientation, and toxic gas exposure.
- Define effects of high OPTEMPO/PERSTEMPO on soldier and unit readiness.
- Transition caffeine research to a caffeine product or guidance for caffeine use.

- Determine factors that limit performance of physically demanding tasks.
- Identify noninvasive methods to predict psychological stress effects and impending physiological crisis, and develop strategies to counteract stress effects on performance.
- Identify and characterize health or performance risks associated with military systems, including the use of cockpit airbag systems, head-supported devices, lasers, and RF radiation-emitting devices.
- Complete brassboard system for rapid microbiological and toxic water contaminants that interfaces with CW/BW water monitoring system.

Challenges

Soldiers must be prepared for immediate worldwide deployment under any environmental condition with maximized performance capabilities. Defining strategies and products to protect, sustain, and enhance soldier performance under these conditions requires the development and application of scientific data and models of soldier performance and health. Strategies and products must remain effective in various combinations under realistic operational conditions. Challenges include:

- Understanding the function of sleep and the neurological basis of mental fatigue.
- Modeling soldier performance in adverse environments as functions of hydration, nutrition, clothing, and work intensity.
- Exploring methods to prevent long-term functional damage from military stressors.
- Modeling human performance.
- Fusion of physiological sensor information
- Muscle repair mechanism and enhancement.

4 Combat Casualty Care

Combat casualty care focuses on the evaluation of feasibility of concepts for drugs, biologics, and diagnostics for resuscitation and life support as well as the development of initial prototypes of trauma care systems for advanced testing, emphasizing products for forward medic and surgeon use. An underlying theme is the definition of key diagnostic and prognostic variables and algorithms that can be incorporated into medical decision support systems and autonomous (i.e., computer-directed) life-support systems.

Goals

The primary goal is to provide technologies that save lives far forward and maintain critical care at all levels of the battlefield. Combat casualty care research must improve the delivery of far-forward resuscitative and surgical care in order to overcome challenges to healthcare delivery posed by a battlefield that increasingly will be geographically dispersed, with limited medical personnel and support capability and extended patient evacuation times. Secondary goals are to reduce evacuations due to dental disease and reduce the medical footprint on the battlefield.

Challenges

Developing effective interventions for far-forward casualty care requires the application of new biological knowledge and the adaptation of existing materials and signal-detection and signal-processing technologies to new applications in biological systems and to the unique needs of the battlefield environment. In many cases, evaluation of candidate technologies depends on animal models to identify those candidates with the highest potential to demonstrate both safety and

efficacy. Ultimately, all medical products must satisfy FDA requirements for safety and effectiveness. Major technical challenges include:

- Delivering local hemostatic agents to internal bleeding sites without surgery.
- Identifying early prognostic physiological indicators of shock, and developing corresponding noninvasive or minimally invasive sensing technologies.
- Measuring real-time human physiologic responses to trauma in prehospital trauma settings.
- Understanding the complexity of mechanisms responsible for brain edema and cytotoxicity following head injury.
- Integrating lightweight battery energy generation and computing capability necessary to support computer-aided diagnostic systems.
- Long-term storage of blood products without in-theater pretransfusion processing requirements.
- Improving knowledge regarding the physiologic and cellular factors underlying the body's response to hemorrhage and subsequent resuscitation.
- Reversing complex detrimental inflammatory and physiological cascades initiated by reduced blood flow and anoxia subsequent to hemorrhage.

Technology Objectives

Table IV–9 identifies technical objectives for Biomedical applied research.

TABLE IV–9. TECHNOLOGY OBJECTIVES FOR BIOMEDICAL

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Infectious Diseases of Military Importance	New & improved vaccine technologies Rational drug discovery program Improved vaccine adjuvants *P. falciparum* malaria genome sequencing	Molecular & genetic understanding of drug resistance in parasites Rapid, nucleic acid-based field diagnostic device Advanced vaccine adjuvants DNA vaccines *P. vivax* malaria genome sequencing Implementation of genetic sequence information into vaccine & drug design Vaccines for dengue, scrub typhus, Hantavirus, vivax and falciparum malaria, & bacterial causes of diarrhea	Combined oral vaccines Single-dose vaccines Handheld, integrated common diagnostic platform Drug treatments & pretreatments for infections caused by hemorrhagic fever & other lethal viruses
Medical Chemical & Biological Defense	Next-generation plague & anthrax vaccines Vaccines against validated biological threats Therapeutics for orthopox viruses Common diagnostic systems for BW threats Genome sequencing of validated BW threats Multiagent vaccine delivery concepts Rational drug design Advanced anticonvulsant	Bioengineered toxin scavengers Advanced diagnostic systems Novel delivery concepts for CBW countermeasures Incorporation of genetic sequence information into design of medical countermeasures to CBW threats Vaccines & therapeutics for emerging biological threats Next-generation vaccines & therapeutics against validated biological threats Immunomodulation for protection & treatment Active topical skin protectant Chemical agent prophylaxis Medical countermeasures against vesicants	Receptor targeted therapeutic agents Broad-spectrum chemical agent pretreatments Immunomodulator/vaccine combinations for protection from biological agents
Military Operational Medicine	Dietary supplements to regulate metabolism for optimal body temperature & performance Reliable assessment methods of individual & unit stress levels Strategies to optimize performance in hot environments Health risk predictions for blast & blunt trauma injury Alertness enhancing drugs Training strategies & dietary supplements to improve physical task performance	Drugs to optimize fat metabolism & preserve lean tissue in operational environments Noninvasive monitoring of cognitive status & readiness Activation of antioxidant enzymes to protect tissues against mechanical & toxic hazards Neck fatigue & injury models Strategies to eliminate stress fractures in training Biochemical indicators of impending musculoskeletal injury	Physiological strategies to reduce water requirements Behavioral strategies to regulate neurohormones to sustain optimal performance Antifreeze proteins to protect against cold injury Integrated biomechanical injury & performance models Genetic markers of injury susceptibility Strategies to enhance muscle tissue repair
Combat Casualty Care	Fibrin-based hemostatic wound dressing Blood sterilization Noninvasive sensors for blunt trauma or penetrating wound detection & remote triage Improved tourniquet New dental field operating system reduces weight of forward dental team by 2,700 lb	Blood-borne pathogen testing kit Antiplaque/anticaries agents in storage & delivery system Far-forward hemostatic agents for internal bleeding Neuroprotective drug identification for clinical trials Components for virtual reality medical skills trainer for field trauma care	Optimization of physiological sensors Pharmacological intervention for secondary damage from penetrating brain injury Peptides for prevention of dental disease Prognostic & diagnostic physiological indicators for remote triage and computerized, autonomous patient care

J CHEMICAL/BIOLOGICAL DEFENSE

The National Defense Act for FY94, Public Law 103–160, consolidated management and funding of both medical and nonmedical CBD programs under OSD in separate defense accounting lines. The law designated the Army as executive agent. In that capacity, the Army presents the nonmedical CBD programs in this section and the medical CBD programs in Section IV–I, "Biomedical."

The CBD program is design to enhance NBC survivability throughout the battlespace. The CBD program includes technological efforts to maximize a strong defensive posture in a biological or chemical environment, using passive and active means as deterrents to the use of weapons of mass destruction (WMD). These means include CB detection, information assessment (including identification, modeling, and intelligence), contamination avoidance, decontamination, protection of individual soldiers and equipment, and collective protection against WMD. The ability to rapidly defeat, warn, protect, and recover in a nuclear, biological, or chemical environment is a major deterrent to the use of WMD.

Through the Joint Future Operational Capabilities (JFOCs) prepared by the Joint Service Integration Group, the services are providing NBC capabilities required for the long term. The Army (and other services) S&T community is an integral part of the JFOC process; JFOC is a major document in preparing the S&T plan and program. Battle management is receiving more emphasis from the user and from the technical community; networking and integrating sensors and detectors and automatically reporting their collected data and information into the services and Global Command and Control Systems are a high priority. The impact of fourth-generation agents on current and future systems is also being investigated.

Technology Subareas

The Army's CBD applied research program is structured around five technology subareas: Contamination Avoidance, Protection, Decontamination, Modeling and Simulation, and Smoke and Obscurants.

The CBD technology area is devoted to the development of technology to counter the threat of CB weapons and ensure the safety and mission effectiveness of FCS forces operating within a contaminated environment with minimal impact on logistics. The strategic goal of CBD is the seamless integration of technologies from its five subareas into a system-of-systems for horizontal integration across the spectrum of combat and support systems. Contamination avoidance, including detection and warning capabilities must be integrated to provide a cohesive picture of the operational theater through the use of information technologies, such as simulation, to provide operational commanders with the required situational awareness needed for command decisions. When contamination avoidance is not possible, integrated protection for CBW will allow FCS forces to maintain operational effectiveness in a contaminated environment with minimal impact on logistics. Decontamination may be required for personnel, mission-essential assets, and areas in CBW conflicts, particularly for power projection supply and retrograde operations. The CB program is focused to meet the needs of the FCS force structure. FCS requires collective protection, NBC sensors on individual vehicles, and a unique, integrated sensor suite for battle management.

1 Contamination Avoidance

Sensing is key to avoid contamination, take protective action, and restore combat power. The goal of sensing is to develop a cooperative detection system that interfaces with current command, control, communications, computers, and intelligence (C^4I) networks and future battle management systems. The cooperative detection system consists of NBC surveillance, detection, identification, monitoring, and reconnaissance elements operating on the existing C^4I, surveillance, and reconnaissance (C^4ISR) architecture and feeds into the NBC battle management system. By 2010 and beyond, as both sensor technology and the network mature, sensors will be integrated into all battlefield systems across all services. These will be smart sensors that detect, identify, and warn of all NBC and toxic industrial material (TIM) threats and can be rapidly programmed for new threats as they are developed and used by the adversary.

Goals

A major goal in contamination avoidance is development of an early warning capability against CB agent attack. Standoff short-range CB detection is being pursued with laser-based systems that can detect, identify, and map chemical vapors, aerosols, and liquids on the ground at ranges of 5–10 km. In the future, biological threats will be detected at ranges up to 50 km using eye-safe lasers with enhanced imaging capability that will employ polarization and multiple wavelength excitation to increase discrimination range against natural biological backgrounds (Figure IV–13).

FIGURE IV–13. PORTABLE HANDHELD UV LIDAR

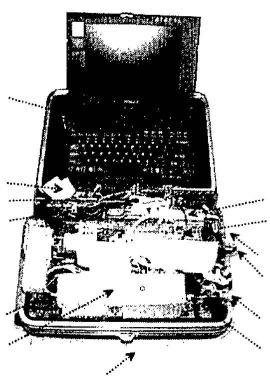


FIGURE IV–14. PYROLYSIS GAS CHROMATOGRAPHY ION MOBILITY SPECTROMETER

The continued evolution of passive chemical standoff detection technologies, such as Fourier Transform Infrared Spectroscopy, toward imaging capability requires development of spectroscopic databases, detection algorithms, optical telescope designs, and high-speed data processing for airborne platforms (FY06). Other assets already conventionally fielded for other purposes, such as radar and acoustic sensors, will be evaluated for signatures that can indicate the use of CB munitions (Figure IV–14).

In addition to standoff solutions to the early warning detection challenge, arrays of small point sensors represent a component of the complete solution. Small chemical sensors that can discriminate chemical agents against ambient vapors are being developed based on surface acoustic wave and ion mobility spectrometric technologies (FY07). These devices will be applicable for individual soldier fielding or in networked arrays. In the mid term, optical sensors for detection of biological aerosols in the ambient background will be available for use in arrays for biological aerosol cloud detection or for use as triggers for ensemble biological identification systems. In the longer term, techniques will be developed to detect biologicals and identify chemicals within a single handheld unit that can be used alone or in networks (FY10). The final solution to the early warning challenge is envisioned to be a network of standoff and point sensors whose outputs are analyzed by sophisticated information management systems to deliver a warning to field commanders through the C^2 architecture.

Solutions to field identification of biological agents will be implemented through systems that sample the aerosol based on triggering resulting from an indication of an increased biological content in the atmosphere, identify the biological agent by recognition of specific target characteristics, and collect a sample for confirmatory analysis in a theater or national laboratory. Near-term identification technologies rely on immunodiagnostics via antibody–antigen interaction. An array of approaches based on immunochromatography, optical sensors, and force differentiation are becoming available. Research is being conducted to develop and evaluate next-generation solutions to identification using polymerase chain reaction and genetic probes for increased specificity and using mass spectrometry for increased range of detectable target agents.

Current efforts will automate the sample preparation required for these next-generation approaches for potential incorporation in the Joint Biological Point Detection System being developed under the DoD CBD Program (FY10). The reagents necessary to support antibody- and gene-based identification are being developed and optimized for current and near-term fielded identification systems. Recombinant antibodies will ultimately be designed and quickly selected from genetic "super libraries" to have specific detection capabilities, and novel starburst dendrimers are being studied for use on tailored reactive surfaces and handheld immunoassays. Combinatorial peptides are beginning to be evaluated as potential new antigen recognition elements. As reagents and assays are developed, optimized, and validated, they will be transitioned to the Critical Reagents Program of the DoD CBD Program.

Of critical importance for all point biological detection and identification approaches is bioaerosol sampling, because characteristics (e.g., concentration of detectable units per unit volume of air) of biological aerosols differ dramatically from chemical vapors, with resulting effects on detection efficiency. The currently employed, large high-volume samplers will be inappropriate for future-generation (FY10) point sensors that are targeted to be handheld devices. Advances leading to smaller, more efficient aerosol samplers are being pursued over the near to mid term. Other goals include:

- Detection of CB agents and toxic industrial/agricultural chemicals (TICs) and TIMs against a high and variable background of ambient material over tens of square kilometers in real time.
- Miniaturization of sensor components using nanofabrication techniques.
- Design and production of biological recognition sites such as genetic probes and recombinant peptides.
- Rapid sampling of aerosols and vapors, and modeling their behavior under different meteorological conditions.

Challenges

The proliferation of a broad spectrum of CB agents such as bioregulators, toxins, viruses, and bacteria and the potential for genetically engineered pathogens have greatly complicated this task. The ideal detection system would operate continually in a standoff mode and would be capable of detecting all known—and even unknown—agents.

The joint CB contamination avoidance modernization strategy is focused on battle management, point detection for biological agents, and remote detection and early warning for both chemical and biological agents. This strategy directly supports FCS initiatives to provide detectors for individual vehicles and a unique, integrated NBC sensor suite for battle management.

2 Protection

Individual and collective protection must protect FCS (and the entire Joint Force) and allow them to operate safely and effectively while under an NBC threat or in an NBC hazard area. The focus of individual protection is to reduce the physiological burden of the protective mask and clothing, thereby lessening performance degradation, integrating the mask into future soldier systems, and protecting against future CB threat agents without sacrificing the broad spectrum of protection against CBW agents.

Goals

New materials are needed to decrease breathing resistance (FY05) and increase binocular vision (FY05). CAD and rapid prototyping techniques are being employed to improve both mask performance and manufacturing processes. Supporting this, new physiological and protection tests are being developed. For clothing, selectively permeable and smart membranes are being assessed for enhanced protection and reduced heat stress. Selectively permeable membranes laminated to lightweight shell fabrics will provide low-thermal insulation and high-vapor transmission.

Collective protection S&T efforts focus on advanced filtration and sheltering concepts for assembled troops that promise to reduce the power, weight, and volume of systems as well as to improve protection against CB threats. Efforts to enhance vapor and aerosol filtration are concentrating on novel materials and processes (Figure IV–15).

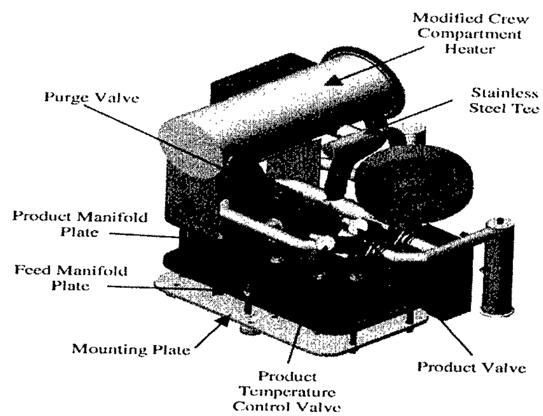


FIGURE IV–15. TSA/PSA REGENERATIVE FILTER

Temperature swing adsorption (TSA), pressure swing adsorption (PSA), and catalytic oxidation (CATOX), as well as improvements to existing single-pass filter systems, are under investigation to provide new systems requiring reduced logistical support through greatly increased service life and improved reliability against an evolving CB threat (FY01). Additionally, adsorbent materials with desirable surface characteristics and precisely controlled pore structures are under investigation to identify improvements to the traditional activated carbon substrates (FY10). Also underway are investigations of the integration of regenerative filtration technologies into host weapons systems, the ability to incorporate a miniature (e.g., surface acoustic wave) sensor into a filter bed to signal impending loss of its filtration capacity, and the performance of fielded filters against nonstandard threat materials such as industrial vapors.

Finally, modeling efforts to describe filter performance based on fundamental properties and process parameters are in progress. Efforts to improve shelter technology are concentrating on novel materials that are more affordable and provide better protection against a broad range of NBC agents.

Challenges

The principal challenge is to identify new materials offering improved protection against a broad and evolving spectrum of CB agents while reducing the physiological burden to the soldier. Indi-

vidual protection and collective protection efforts have been significantly reduced and refocused to support the Army's FCS initiatives. Of particular importance to FCS are regenerative filter systems to provide protection against liquid, aerosol, and vapor threats. More specifically:

- Apply new adsorbent technology and materials to improve the performance of TSA and PSA processes as well as traditional single-pass filtration systems.
- Identify new catalytic materials to efficiently destroy chemical agents while minimizing the production of hazardous byproducts.
- Develop lighter tent materials with improved protection properties.
- Identify practical regenerative particulate filtration concepts and systems.
- Expand the understanding of integrating standard and regenerable filtration technologies into host systems.
- Develop improved modeling approaches that will permit fast-track maturation of new filtration processes.
- Develop high-performance, broad-spectrum individual filtration (TIMs).

3 Decontamination

The ability of U.S. forces to conduct decontamination is an essential component of force protection. Today's Army must be prepared to fight in a contaminated environment. Having the capability to remove, neutralize, or destroy such contamination is a key component in restoring the combat power of units.

Lessons learned from the past show that current decontamination methods and capabilities are inadequate to keep pace with the Army transformation. Units must be able to decontaminate faster, more effectively, with minimum amounts of water, and without damaging sensitive equipment while sustaining operations. Developing decontaminants, delivery apparatus, and doctrine are ongoing efforts that will help ensure survivability in contaminated environments.

For the Legacy Force existing M17 Lightweight Decontamination Systems will be maintained. Chemical Corps dual-purpose (smoke/decon) units will be equipped with the Modular Decon System. The Objective Force will be equipped with the new decontaminants and applications that ultimately are selected from the Joint Fixed Site Decontamination and the Joint Sensitive Equipment Decontamination programs.

Goals

The major goal is to develop effective, environmentally safe CB decontamination systems to deactivate toxic materials without damaging the contaminated surface or affecting the performance of the equipment being decontaminated. Restoration capability is to enhance warfighter sustainability by providing the ability to completely recover and restore combat power to the affected force or facility after an NBC (including TICs and TIMs) or WMD event occurrence(s). There are specialized requirements for the decontamination of sensitive equipment items, parts, and components. A mid-term requirement is to replace Decontamination Solution 2 (DS2), while a long-term requirement calls for the ability to decontaminate the interiors of aircraft and other vehicles.

Catalytic enzymes are a major thrust of DTAP DTO CB.09, "Enzymatic Decontamination." An enzyme that degrades G-class nerve agents has been scaled up and produced via biomanufacturing, and was subjected to a NATO field test in FY98. Enzymes that degrade V-class nerve agents were screened for efficacy and down-selected for scale-up in FY98. Demonstration of the efficacy and stability of enzyme and chemical decontamination systems for G-, V-, and H-type agents in focus, detergent solutions, and other types of dispersion systems is scheduled for FY02. Ultimately, these new catalytic materials may be incorporated into sorbents and self-decontaminating coatings, fibers, or paints (FY10) (Figure IV–16).

FIGURE IV–16. ENZYME FOAM DECONTAMINATION

Challenges

The primary technical objective is to design decontaminating materials with highly reactive or catalytic properties, long shelf life, environmental acceptability, and noncorrosive qualities. They must function effectively against a multitude of threat materials under a broad range of temperatures, and they must reduce the logistical burden on the forces. Army initiatives in decontamination are intended to increase the mobility and sustainment of the FCS-equipped forces on the battlefield. Joint and Army initiatives are synchronized. Challenges include:

- Finding suitable liquid decontamination media, including surfactant systems or an environmentally acceptable organic solvent, to serve as the vehicle to carry decontaminants and dissolve thickened agents.
- Identifying technology to perform interior decontamination that is compatible with electronic equipment and a wide variety of surfaces.
- Sorbents are an effective way of removing CB contamination from surfaces. However, they either do not neutralize the contamination once removed or do so at a very slow rate and thus tend to release absorbed contamination over time. Technologies are just becoming available from basic research that will address reactive sorbent materials.

4 Modeling and Simulation

M&S is an essential enabling tool in the concept exploration and the development, requirements analysis, and battlespace management of CBD systems. Warfighting experiments have emerged as a critical aspect of the requirements development process and in evaluating the suitability of CBD systems to sufficiently meet warfighting needs. These warfighting experiments will be both joint and service specific. They include AWEs, Battle Laboratory Limited Objective Experiments, and evaluations of an ACTD. The live testing constraints amplify the relevance and utility of M&S for CBD systems. Sufficient M&S tools and CBD system representations are required for the engagement, mission/battle, and campaign levels of M&S. A high-level architecture (HLA) federation approach similar to that depicted in Figure IV–17 will be built upon to meet future experiment, evaluation, and analytical needs. Each battle laboratory or AWE simulation and C^{4}I network will be different; adaptations will be required (2001–08). Maintaining a set of common and flexible tools will be extremely valuable to the community (2002). CBD system representations should be adjustable on the engineering level (2002). This is particularly true for CB sensors

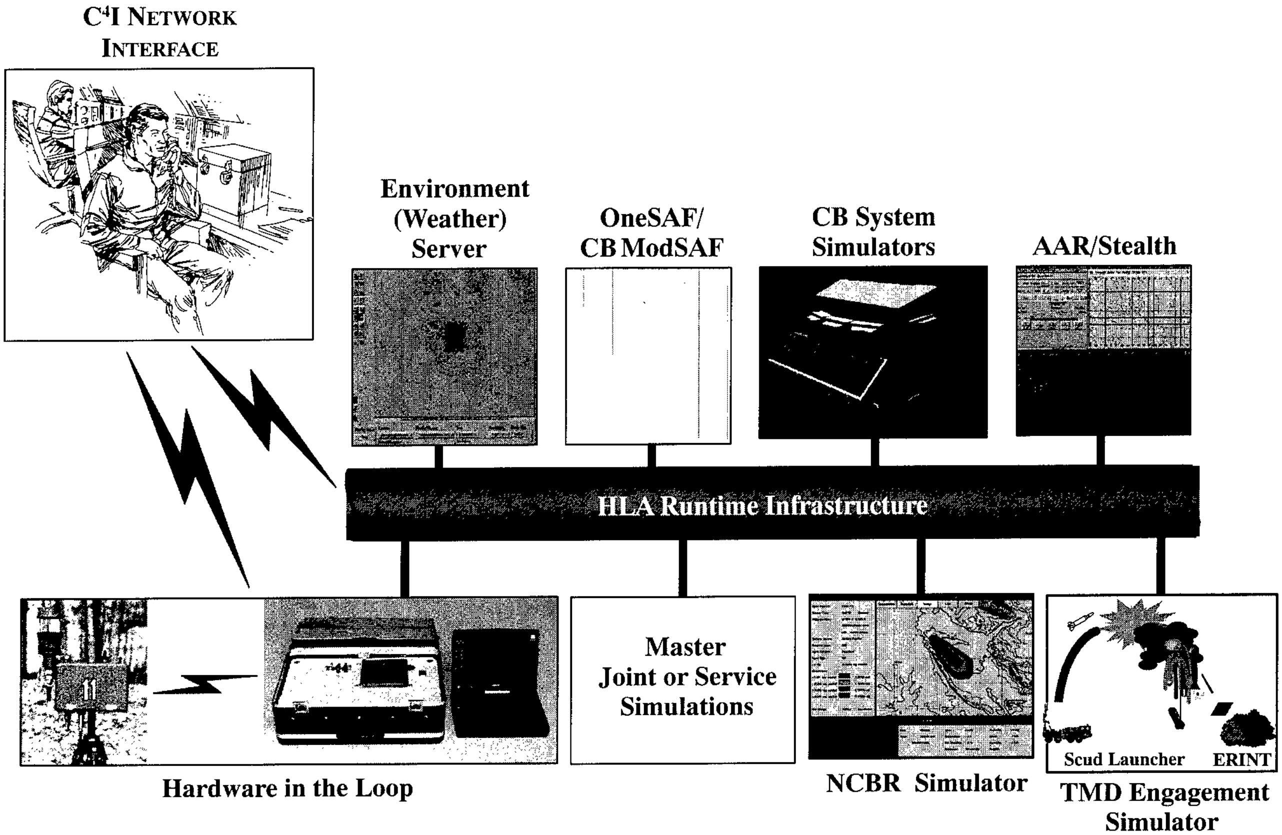


FIGURE IV–17. CB M&S SIMULATION SUITE TO SUPPORT TECHNOLOGY AND SYSTEM DEVELOPMENT

and detectors. A common CB dial-a-sensor representation that can be appended to multiple diverse platform representations should be able to serve both standoff and point detection for chemical, biological, radiological, and toxic industrial agents (2002). As currently practiced, actual hardware-in-the-loop will be stimulated by the simulation, and in turn will provide feedback to the C^4I network.

Transport, diffusion, and de-absorption of chemical agents need to be efficiently modeled within the complex urban environment for collateral, terrorist, or military releases. Simulation in the urban environment is particularly challenging; however, it is the environment in which future forces will be required to operate. Integrating microscale meteorology is critical. The appropriate synthetic environment (2003) must support applied simulations for force operations, survivability, decontamination, and restoration in the Joint Urban Battle Space (2003–08).

The One Semiautomated Force (OneSAF) objective system development (2004) will be in position to support the interim and objective forces. The need exists to build on the HLA-compliant nuclear, chemical, biological, and radiological (NCBR) simulator and the OneSAF baseline efforts to ensure that the necessary CB M&S capability meets the needs of experiment, evaluation, analysis, and training of the Interim (2002) and Objective Forces (2008). The OneSAF baseline and the legacy simulations of the Close Combat Tactical Trainer, Janus, and others will serve the surrogate force.

Integration into the simulation federations that serve the joint community and the Army will require continual maintenance as the various simulation centers, analysis centers, and battle laboratories evolve.

Under the Army's Simulation Modeling for Acquisition, Requirements, and Training (SMART) process, the CBD programs will be required to provide robust representations of their system for inclusion and integration into service and joint simulation federations for training, analysis, and acquisition. Common tools that promote reuse and interoperability are the keys to cost avoidance, efficiency, effectiveness, and participation. The development and maintenance of a common M&S toolset that the CBD combat developer, material developer, and warfighter can rely on is critical (2002–12).

Challenges

The application of simulations to assess the performance of CBD systems in the emerging battlespace is critical. The need exists to predict the threat potential of existing and new agents against warfighters, their equipment, and their immediate surroundings. Challenges include:

- Agent transportation, diffusion, and fate modeling in the urban battlespace for (1) urban sectors of varying dimensions, configurations, and contents; and (2) diverse structural interiors.
- The appropriate representation for the assessment, planning, and training of decontamination and restoration operations.
- The ability to quickly and efficiently integrate into federations that support force analysis, warfighting, and material evaluations.
- A validatable and verifiable capability to analyze CB defense systems, particularly sensors, in existing constructive and virtual simulations.

5 Smoke and Obscurants

Although smoke and obscurants are not traditionally thought of as part of CBD, they are contained within the NBC work area. The smoke and obscurant countermeasure technology development area is unique to the Army. The purpose is to support system and troop survivability. This is accomplished by gaining information dominance over the enemy by attacking or deceiving enemy reconnaissance, intelligence, surveillance, and target acquisition; shielding friendly formations and fixed sites; and protecting vehicle assets from smart weapons (Figure IV–18).

Goals

The threat EO spectrum is divided in three main areas: visual, IR, and millimeter wave (MMW). A specialized requirement exists for an MMW material and dissemination improvement for the M56 Smoke Generator (MMW P^3I, FY00). More broadband or multispectral smoke is needed in the long term to screen in the visual, IR, and MMW. Current materials in the IR and MMW must be improved to reduce the logistics burden and to increase effectiveness. Nanofiber and nanotube technologies are being investigated as potential solutions for increased performance. In addition, delivery and dissemination technologies are being investigated as part of the vehicle protection, multispectral smoke pot, and distant smoke programs. A rapid obscuration system with increased protection for vehicles is being pursued using propellant dissemination technology. This same technology is being investigated for applications for the multispectral smoke pot. New delivery techniques for the use of distant smoke are being investigated. Concepts include UAVs and UGVs.

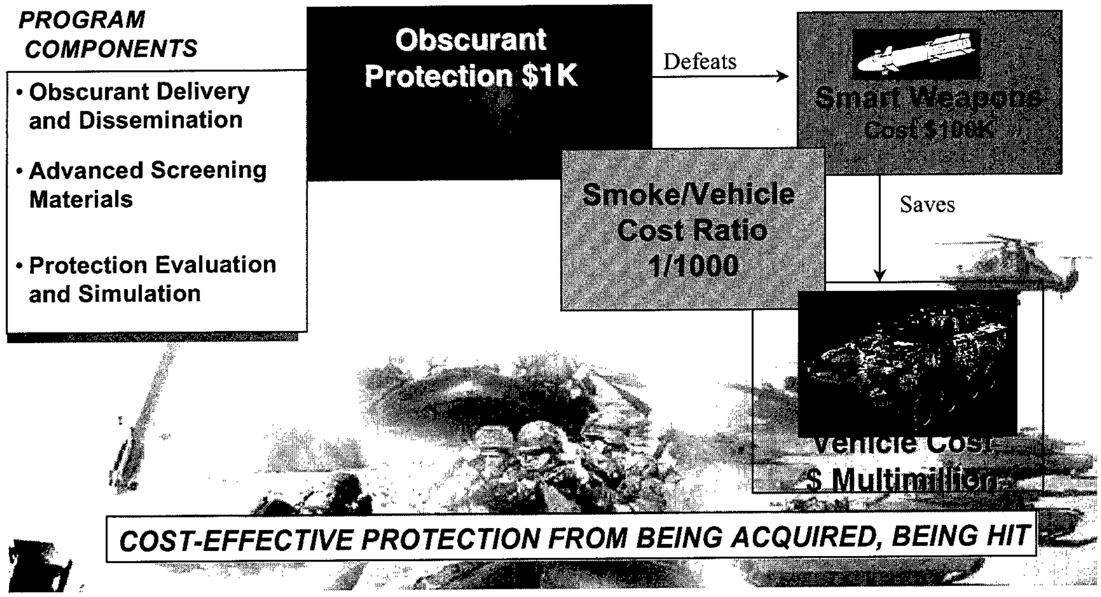


FIGURE IV–18. OBSCURANT PROTECTION

Challenges

The goal is to develop environmentally safe, low-cost materials covering the full EO spectrum. These higher performing materials are required to reduce logistics and provide more feasible payloads for multispectral smoke pot and distant smoke applications. Challenges include:

- Develop a multispectral material to cover all threat spectrums of interest (visual, IR, MMW).
- Develop more efficient methods of disseminating aerosol obscurant materials.
- Verify theory of particle characteristics through evaluation of materials.
- Investigate emissive countermeasures as enhancements to existing obscurants.

S&T efforts in smoke and obscurants directly support increasing protection and survivability of the Objective Force. Obscurant M&S will function in support of other efforts employing the SBA/SMART process and support the development of the Army transformation's situational awareness, strategic, operational, tactical, and engineering M&S studies and analysis efforts. Specific M&S technologies still needed are modeling of obscuration behavior on open terrain and in complex or urban terrain, accounting for atmospheric effects in a synthetic environment, integrating obscurant management systems in C^4ISR representation in wargame simulations, and better portrayal of obscuration, sensor, platform (both air and ground), and protection capabilities in these same simulations.

Technology Objectives

The technology objectives for Chemical/Biological Defense are shown in Table IV–10.

TABLE IV–10. TECHNOLOGY OBJECTIVES FOR CHEMICAL/BIOLOGICAL DEFENSE

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Contamination Avoidance	Genetically engineered antibodies	Genetic super library Early warning of bioagent detection at 1–5 km Automated single-step point detection Subsymptomatic chemical agent interior monitor Early warning of aerosol cloud at 5–50 km Standoff chemical detection at 20 km CB water & surface contamination monitor Wide-area detection	Lightweight CB detection from UGV/UAV platforms Miniaturized photo-array detection/identification of biological agents Handheld integrated CB detection system
Protection—Individual	24-hour liquid protection 50% reduction in breathing resistance 50% increase in binocular vision Develop advanced, selectively permeable membrane eliminating or reducing the use of carbon in chemical protective ensembles	Expanded performance degradation model Compatibility with future soldier systems Improved filtration systems	Fully integrated CB ensemble New super-dense absorbents Smart barrier membranes
Protection—Collective	Prototype PSA system Laboratory-scale TSA system	Combined PSA/TSA/CATOX system Engineered absorbents	Monolithic filtration media
Decontamination	System for decon-sensitive equipment items New general-purpose decon solutions	Automatic decon through conductive coatings System of decon of interior spaces & electronics Concepts for wide-area/fixed-site decon New polymers with agent reactive sites for more efficient decon	Self-decon coatings Reactive sorbent decontaminants
Modeling & Simulation	DIS capability for CB detectors	Upgraded wargames, simulations, & virtual representations of CBD equipment Sophisticated proficiency in complex urban environments	Full SBA/SMART Virtual & actual CBD equipment in fully integrated constructive & virtual combat simulations
Smoke & Obscurants	Investigate new dissemination methods Cost-effective MMW materials	Higher performing IR obscurants Improved obscurant M&S tools New concepts in vehicle protection	Higher performing multispectral materials (visual, IR, MMW)

K ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY

Technology efforts in this area solve critical civil engineering and environmental problems relating to training, mobilizing, deploying, maneuvering, protecting, and sustaining the force at any location at any time. It also addresses research into mobility and countermobility, including mine and countermine technology. These efforts directly support the Army's transformation to a more responsive, deployable, agile, versatile, lethal, survivable, and sustainable force. The applied research will help shape the transformation of the Army through its enhanced capabilities for executing mobility, countermobility, survivability, and general engineering missions.

Technology Subareas

The Army's Engineering, Combat Construction, Mobility, and Countermobility applied research program is structured around three technology subareas: Civil Engineering, Environmental Quality, and Mobility and Countermobility.

ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY-RELATED STOS
Civil Engineering
Munitions Production Compliance Technology
Airfields and Pavements To Support Force Protection
Force Protection of the Battlefield
Lines-of-Communication (LOC) Assessment and Repair
Force Protection Against Terrorist Threats
Buried Unexploded Ordnance (UXO)
Environmental Quality
Sustainable Military Use and Stewardship of Army Lands
Environmental Cleanup
Mobility and Countermobility
Advanced Bridging Virtual Prototyping Technology
Obstacle Marking and Vehicle Guidance
FCS Mine Detection and Neutralization

1 Civil Engineering

Civil engineering includes survivability and protective structures, airfields and pavements, sustainment engineering, and conventional facilities.

The Army's survivability and protective structures S&T program performs research that enhances force protection, from the foxhole to fixed facilities, against weapon threats ranging from small arms and terrorist weapons to advanced conventional weapons equipped with multispectral sensors. The research will provide technologies that increase the survivability and sustainability of deployed forces, while reducing their logistical footprint. This will allow forces to be more responsive, deployable, and agile through the development of lightweight, reliable materials and new techniques for use in (1) expedient base camp and theater missile defense

(TMD) protection, (2) camouflage, concealment, and deception by signature manipulation, (3) terrorist protection from asymmetric threats, and (4) breaching for MOUT operations.

Airfields and pavements technology provides the U.S. military with a reliable launching platform to project mobile forces to support worldwide contingency conflicts. Sustainment engineering is structured to provide the civil engineering technologies required by the Army for successful execution of land-, air-, and sea-based sustainment operations in support of projected U.S. forces.

The primary thrusts in the conventional facilities area are to develop technologies to revitalize and operate DoD's aging infrastructure; ensure a continuum of facilities for the evolving Objective Force; support the training, readiness, and force projection; maximize productivity of resources in acquisition, revitalization, operations, and maintenance and repair (M&R) management; and improve soldier and family quality of life.

Goals

The survivability and protective structures program goals are to reduce standoff distances for protecting the forces against asymmetric terrorist weapons threats by 30 percent in FY02, and provide integrated blast, ballistic, and low-signature engineering support protective measures to reduce target acquisition distances and increase survivability from battlefield weapons by 25 percent in FY02.

In airfields and pavements, the goal is to reduce costs by 20 percent, minimize seasonal impacts, and extend the life (5 to 10 years) of the Army's military-unique roads, airfields, ports, and railroads. Sustainment engineering technology will support a deployed force in an austere theater with faster, lighter, less voluminous, and less manpower-intensive ways of executing mobility, countermobility, and general engineering missions.

The conventional facilities goal is to achieve a 20 percent reduction in facilities acquisition and M&R costs from 1990 levels and a 30 percent reduction from 1985 levels in energy consumption by FY05.

Challenges

Challenges include:

- Lack of mechanistic models to predict airfield performance.
- Inadequate understanding of road and airfield behavior under load and climate.
- Lack of adequate materials and methods for rapid, expedient airfield construction.
- Lack of information on terrorist weapon effects and response of conventional buildings and components.
- How to effectively and affordably apply high-strength/-ductility materials for blast mitigation and retrofit.
- Lack of economical, lightweight materials for both expedient structural support and ballistic protection.
- Lack of economical camouflage and concealment materials with multispectral characteristics.

2 Environmental Quality

Environmental quality includes cleanup of contaminated sites, compliance with all environmental laws, pollution prevention to minimize Army's generation of wastes, and conservation of natural and cultural resources to sustain training and testing lands.

Goals

The site cleanup goals are to reduce cost and expedite cleanup programs while ensuring protection of human health and the environment. Research is conducted in characterization and monitoring (with emphasis on detection and discrimination of unexploded ordnance (UXO)), remediation technologies, and fate and effects of environmental contaminants in all climates. Cleanup R&D will produce innovative and cost-effective site identification, assessment, characterization, advanced cleanup methods, and monitoring technologies. Advanced sensors and sampling devices will expand the capabilities and precision of these systems. Subsurface conditions will then be better understood, thus increasing the efficiency of UXO detection, in situ biological treatment, passive subsurface water treatment, improved chemical immobilization concepts and methods, and improved analytical concepts to determine contaminant risk assessment of specific sites. Techniques will be developed to more accurately and rapidly determine the fate, transport, and effects of key DoD contaminants in soil and groundwater in all climatic conditions.

Compliance research will provide technologies for advanced "end-of-the-pipe" control and treatment of hazardous and toxic gaseous, liquid, and solid wastes when pollution prevention is not possible or cost effective to maintain the military and industrial base readiness. Army systems, operations, and processes will be developed to meet existing and anticipated air, water, land, and noise regulations. Research is focused on (1) characterization of pollutant and waste behavior, (2) media-specific control and treatment technologies, and (3) monitoring and assessment tools. Pollution prevention research will provide the Army with alternative materials, innovative manufacturing processes, and enhancements to daily activities to enable the Army to operate current and future production plants as well as to use its weapon systems. Overall efforts are focused on minimizing compliance requirements through new systems and processes that prevent or minimize pollution, with attendant reduction in production and product treatment costs.

Conservation research will provide the S&T required for sustainable use of the Army's training lands and firing ranges. Research will provide the Army with the understanding and technical capabilities necessary to protect and improve the biophysical resources that are needed for sustainable lands and ranges, to accommodate force transformation, and to provide support to the Objective Force. The research is focused on developing cost-effective technologies to mitigate military impacts, rehabilitate damaged resources, comply with environmental regulations, and support sustainable ecosystem management. Technologies are intended to reduce or eliminate environmental restrictions on military use of installation land. The goal is to develop the assessment, monitoring, and modeling capabilities and provide the integrated framework linking land capacity, land rehabilitation, and species and ecosystems impact models that support the risk-based analysis needed to sustain training and testing lands.

Challenges

Challenges include:

- Complex environments and geophysical site conditions (soil, water, topography, vegetation, and climate).
- Large number, varying concentrations, state of mixing, and yet unmapped contaminants encountered at military-unique cleanup sites.
- National and individual state regulatory requirements.

3 Mobility and Countermobility

This subarea encompasses research into the impact of terrain and weather on mobility and countermobility operations. Research efforts include development of high-resolution, scalable mobility models for vehicle simulators, hydrology modeling, rapid obstacle planning methods, new techniques for emplacement of countermobility barriers, and mine and countermine technologies.

Goals

The goals are to enhance the basic understanding of the interactions between vehicles and terrain; provide this understanding in analytical software for warfighter planners; develop advanced demolition techniques for rapid obstacle reduction; provide improved obstacle planning tools; increase the fidelity and accuracy of hydrology models for river crossing operations; and improve the countermine capabilities in handheld, vehicular-mounted, and airborne applications (particularly in regard to enhanced detection and reduced false alarm rates).

OBSTACLE MARKING AND VEHICLE GUIDANCE STO (2000-2001). This STO is comprised of two integrated components, an intelligent marking system and a vehicle guidance system. The intelligent marking system will use two types of markers, smart markers and master markers. The smart markers are equipped with an optical transceiver that can identify and communicate with any vehicle in their proximity, up to 30 m, by using an IR light emitter or a visible light emitter (such as an LED). The master markers use RF light emitter or a visible light emitter locations to approaching vehicles up to a distance of 1,000 m. Both markers can be remotely turned on and off and can be programmed to store relevant data that can then be disseminated to passing tactical vehicles. The markers will be inexpensive, require minimal power, and have an embedded GPS module. The markers will be able to acquire, store, and disseminate data from military C^4I systems such as the Force XXI Battle Command Brigade and Below. The vehicle guidance system will work in conjunction with the intelligent marking system to enable vehicle crews to maneuver quickly and safely through or around obstacles. The markers will transmit data such as the GPS coordinates of a cleared lane through a minefield or the boundary of a contaminated site. An optical or RF transceiver on board the vehicle will receive these data, which are then input to a tactical crew station monitor. The obstacle, the vehicle itself, and the safe passageway will be digitally represented on this crew station monitor. As the vehicle proceeds through the lane, the crew will make steering corrections using the graphically displayed passageway as a reference point.

ADVANCED BRIDGING VIRTUAL PROTOTYPING TECHNOLOGY STO (2000-03). This STO addresses the future need for a lightweight bridging system mounted on a lightweight chassis that can support both the light/medium brigade and legacy heavy systems. The focus of this research will be advanced materials, virtual prototyping, finite element modeling, and kinematics studies that leverage technologies demonstrated in Composite Armored Vehicle ATDs and the DARPA

Bridge Infrastructure Renewal Program. The goal of this program is to establish a viable, in-stride gap crossing technology that is packaged for a lightweight force. This will be accomplished in part by reducing the bridge system weight by 50 percent.

The FCS Mine Detection and Neutralization STO will develop forward-looking sensor technologies, signal processing, and mine neutralization techniques to address on-/off-route surface and buried antitank mines. The goals are to detect or locate mines 10–30 m in front of vehicles moving at 15–20 kph and to neutralize mines at 10–50 m distance from 10- to 20-kph platforms with a P_k of 90%–95%.

Challenges

The mobility and countermobility challenges are:

- Obtaining more accurate and higher resolution geospatial information.
- Extending situation awareness capabilities.
- Discriminating buried targets from clutter with sufficient spatial resolution and accuracy to locate potential mines.
- Overcoming OPTEMPO limitations of downward-looking countermine vehicle sensors.
- Improving mine neutralization delivery techniques and control of high-order detonation.
- Increasing the probability of mine detection while teleoperated.
- Combining countermine detection and neutralization capabilities.
- Enabling robotic mine neutralization and extraction.
- Developing forward-looking countermine sensor suite with precision location and low-order neutralization.
- Provide obstacle markings and bridges to increase maneuverability.
- Understanding and predicting the impact of seasonal weather on lines of communication; materiel; and tactics, techniques, and procedures.

Technology Objectives

The technology objectives for the Engineering, Combat Construction, Mobility, and Countermobility area are shown in Table IV–11.

TABLE IV–11. TECHNOLOGY OBJECTIVES FOR ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Civil Engineering—Survivability & Protective Structures	Criteria for antipenetration systems to defeat heavy penetrators Procedures for retrofitting roofs & walls of existing facilities to provide protection from vehicle bombs Develop a family of protective systems using advanced materials & design procedures that will increase the survivability of troops (in fighting positions), weapon systems, materiel, & equipment Construction criteria	PC-based design manual for hardened structures Antipenetration systems to defeat very heavy robust penetrators Lightweight, high-strength composite framing elements for hardening structures Deployable protective packages for the initial brigade/interim force Protection criteria for increased survivability of TMD systems	Develop vulnerability assessment model for retrofitting critical facilities to enhance survivability against advanced weapons Develop criteria for survivability of conventional facilities against entire spectrum of terrorist weapons Increase force survivability with 40% reduction in logistics burden Decrease P_d by 50% through advanced multispectral signature management techniques
Civil Engineering—Airfields & Pavements	New materials & design system to increase pavement life at reduced costs Develop database & interactive design systems for pavement prediction Fracture & durability model field validation Develop improved mixture design for quality control & quality assurance	Fundamental understanding & analytical capability to address all aspects of pavement response & behavior Methods & materials for rapid construction of operating surfaces Reduced LCCs & increased durability of DoD's pavement by 10% of FY93 cost Criteria for use of modified asphalts in cold regions	Criteria for APOE power projection platforms Criteria for airfield design & construction to support contingency operations worldwide DoD transportation systems designed with confidence levels of serviceability & performance 25% LCC reduction of FY93 cost
Civil Engineering—Sustainment Engineering	Field demonstrate advanced materials for construction of operating surfaces Validate & document mobility data inference routines for all of the world's major climatic zones Demonstrate obstacle planning software Develop ultra-low dosage cement admixture for frost protection	Reduce construction time in soft soil by 35% Develop first-generation theoretical mobility model Design rapidly installed breakwater First LOTSOS Develop automated bridge classification system Develop thawed soil stabilization techniques for base camps & expedient roadways	Reduce horizontal construction time by 20% Reduce logistic requirements for engineer construction materials by 20% Develop high-resolution mobility model for advanced vehicle platforms Initiate gap/river crossing site selection procedures based on trafficability & crossability
Civil Engineering—Conventional Facilities	Add new building types into current version of MDS to reduce delivery time of Army facilities Develop basic framework for an integrated installation management system to reduce costs of O&M for Army installations Develop integrated long-term utility & energy planning model for Army installations	Investigate rapid construction methods & base camps for transformation and the Objective Force Reduce facilities acquisition & M&R costs by 15% of 1990 Integrate installation management protocols & systems Reduce facility-related greenhouse gas emissions (CO_2) by reducing energy consumption (previously in far term)	Develop advanced technologies for the continuum of facilities required to support the Objective Force in its evolving mission Develop distributed energy technologies for use in the theater of operations in support of transformation and the Objective Force Reduce facilities acquisition & M&R costs by 20% of 1990 Reduce facility-related greenhouse gas emissions (CO_2) by reducing energy consumption
Environmental Quality—Conservation	Address training impacts on threatened & endangered species & land capabilities to sustain long-term training	Address cumulative risk to mission & land resources due to training & testing environmental resource interface	Address the science & decision support needs to manage & sustain mission & resources using a landscape level & ecosystem management approach
Environmental Quality—Cleanup	Predictive sensor models for advanced UXO detection Link comprehensive screening, toxicity, & bioaccumulation models to a risk assessment model framework Pilot-scale demonstration of in situ biodegradation of groundwater	70% reduction in UXO remediation through advanced UXO detection/discrimination Comprehensive ARAMS In situ CB treatment of groundwater contaminated with explosives In situ treatment of inorganic contaminated soil & groundwater at training ranges Onsite assessment visualization	Remote, multisensor UXO detection Combined in situ physical/chemical/biological groundwater treatment of mixed, multiple chemical contaminated sites

TABLE IV–11. TECHNOLOGY OBJECTIVES FOR ENGINEERING, COMBAT CONSTRUCTION, MOBILITY, AND COUNTERMOBILITY (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Environmental Quality—Compliance	Develop activated carbon fiber cloth absorption technology for HAP control from hazardous organic solvents used in Army painting, cleaning, & degreasing operations Develop assessment & design to minimize weather-based propagation of long-term average noise exposure for Army small arms ranges Investigate modified biosorbent technology for treating Army waste streams containing heavy & toxic metals & explosives	Develop reductive electrochemical treatment technology to destroy nitro-aromatics, nitramines, or nitrate esters Develop noise modeling & mitigation techniques & technologies for new weapon systems in the Objective Force Develop source characterization & measurement technologies for particulate matter 2.5 mitigation & atmospheric modeling to determine impact of training on local & regional communities	Develop technologies for environmentally compliant & sustainable base camps for the Objective Force
Environmental Quality—Pollution Prevention	Develop ODS elimination for refrigerants, sealants, & degreasing cleaners Develop laser ignition to replace chemical ordnance for medium- & large-caliber ammunition (avoid toxins during manufacture & demil) Develop improved tools & models for life-cycle environmental analysis to assist weapon designers & program managers	Low-VOC reformulated CARC paints TP elastomer propellants elimination in the manufacturing process Green bullets (elimination of lead in primers & bullet cores) Alternative technologies to avoid open burn/open detonation of energetics (scrap demilitarization)	Green missile (lead elimination & no HCN emission) Halon 1301 replacement for ground tactical vehicles & aircraft engine protection (ODS problem solved) Cleaner processes & products for energetics Aqueous processes for ceramics & composites
Mobility & Countermobility	Identify & evaluate novel sensor technologies & signal processing techniques to detect & classify low & nonmetallic content mines Provide a prototype battlefield marking & vehicle guidance model Provide advanced bridging & launcher mechanism concepts & baselines	Demonstrate & evaluate forward-looking sensors & standoff neutralization techniques Demonstrate high-speed reconnaissance & breaching of minefields Provide first-generation intelligent marking system to PM–MCD; system will include smart markers, master markers, & strap-on vehicle guidance system Provide evaluation of future military bridging & launching concepts using advanced materials through advanced virtual prototyping analysis technology Provide prototype system for evaluation	Provide second-generation intelligent marking system incorporating P^3I upgrades called out in the OMS ORD; marking system will be integrated into existing emplacement platform Provide evaluation of prototype bridging system to include testing under actual field conditions with vehicle crossings, soldier interfacing, & operation within known future Army composition & infrastructure

L LOGISTICS

The operational construct for the objective force poses tremendous challenges to the logistics community. Advanced maneuver and warfighting concepts such as highly decentralized operations, extremely high tempo, and operational reach will be dependent on similarly radical advances in sustainment capabilities. Objective Force maneuver elements envision being able to operate without sustainment, less Combat Health Support, for periods up to 72 hours.

The Objective Force full spectrum of operations will be the logical beneficiary of the successful execution of the basic components of the *Revolution in Military Logistics* (RML). Those components are a reduction in logistics support requirements attained from more supportable and reliable weapon systems, more accurate and timely logistics knowledge, and more responsive and agile logistics support structures capable of supporting from afar, which will reduce the sustainment footprint on the battlefield.

The revolutionary capabilities projected for the Objective Force will not be achieved unless and until there is a corresponding revolution in military logistics and transformation of combat support and combat service support (CSS). Moreover, the single most important improvement necessary to achieve this RML is a radical reduction in sustainment requirements. Notwithstanding this, the goals and objectives of CSS remain the same—to provide the necessary support at the right time, in the right quantities, and at the right location. The Army's technology development and transition strategy for Future Combat Systems incorporates the technologies that significantly reduce or eliminate the demand for logistics support.

CSS capabilities envisioned to sustain the Objective Force are identified below. Some will require changes in combat platforms and systems that would then result in decreased logistics requirements. The Army can no longer afford an expansive, deployed, military-based CSS infrastructure.

- Develop improved munitions and packaging that are less vulnerable to fire and accidental explosion, improve munitions safety, and reduce weight and cube of munitions.
- Reduce power and energy requirements by at least half.
- Develop systems with real-time diagnostics and prognostics that support higher operational readiness of all systems.
- Develop deployment planning and execution tools that promote timely, responsive, and effective force closure.
- Improve reliability and maintainability of systems and platforms by 50 percent, which significantly reduces unknown battlefield failures through ultra reliability and fail-safe design.
- Develop a real-time logistics C^2 and distribution management capability, linked to maneuver unit operations, that provides situational awareness, total asset visibility, actual and projected consumption rates, and positive control from all sources to the end user.
- Develop resilient communications and information systems that provide accurate, reliable, timely, trusted, and informative data.

Technology Subareas

The Logistics applied research program is divided into six subareas: Early Entry and Resupply, Logistics Demand Reduction—Resupply, Logistics Command and Control—Situational Understanding, Logistics Demand Reduction—System Reliability, Logistics Demand Reduction—Prognostics, and Logistics Demand Reduction—Power and Energy.

LOGISTICS-RELATED STOs
Early Entry and Resupply
Semiautonomous Robotics for FCS
Logistics Demand Reduction – Resupply
Water Purification Technology
Logistics Demand Reduction – Prognostics
Petroleum Oil and Lubricants (POL) Quality Analyzer and Sensors
Remote Readiness Asset Prognostics/Diagnostics System
Logistics Demand Reduction – Power and Energy
High-Energy, Cost-Effective Primary and Rechargeable Batteries
Integrated Power Generation and Management Technologies
Advanced Tactical Fuels and Lubricants
Power Conversion Technology for FCS

1 Early Entry and Resupply

The logistics community requires a capability to rapidly deploy and insert Army assets and supplies into restricted terrain, day or night, in any weather.

Goals

Commensurate with the air insertion of the FCS for the Objective Force, U.S. logisticians need a capability to air insert initial early-entry supplies (ammunition, fuel, and other contingency consumables). To meet the deployment time constraint, logistics modernization must include initiatives that reduce or eliminate the current intermodal shipment delays.

SEMIAUTONOMOUS ROBOTICS FOR FUTURE COMBAT SYSTEMS STO (2000–04). This STO will demonstrate advanced robotic capabilities on a set of combat support and CSS vehicle concepts. The effort will leverage prior technology achievements in the areas of autonomous mobility, architecture, and sensor and robotics system integration; advance the state of the art in these areas; and provide a field demonstration and application of the technologies. The program will culminate in a soldier-operated experiment in 2004. *Supports:* FCS and other OUSD-supported robotics programs, including TUV, Panther/Panther II (mine clearing) systems, and force protection programs.

Challenges

Airdrop challenges include modeling transient parachute-opening processes; developing lower cost, lighter weight, and reduced-volume parachutes; advancing nonparachute decelerator technologies for soft landing of personnel and sensitive equipment; and developing high-glide decelerators for precision airdrop applications. Specific transitions include precision-guided "smart" airdrop systems using (1) high-glide-ratio, flexible-wing technology, and (2) advanced ballistic and semiballistic decelerators that enable greater payloads, offset distances, and accuracy; improved efficiencies in cost of delivery; enhanced survivability of delivery aircraft; and rapid deployment of equipment on the drop zone. Intermodal shipments of supplies and equipment require insertion of advanced "drive-through" weight and balance technologies.

2 Logistics Demand Reduction—Resupply

The critical issue for the Army is to "design out the demand" for logistics in its FCS. Resupply of energy and munitions are currently the most demanding and critical to sustained combat capability.

Goals

While the FCS will provide an unprecedented capability to maneuver on the battlefield, it also places unprecedented demands on the CSS distribution system—CSS's principal problem on the battlefield today—which does not currently possess (nor is it projected to possess) similar cross-country speeds. To avoid suboptimizing or even negating the FCS's cross-country speed capability, the Army must develop and demonstrate an advanced battlefield fuel distribution system or vehicle capable of sustaining the FCS's increase in speed (up to 40 percent). The Army must develop lighter weight, common caliber, multifunctional, and smarter munitions with higher P_k to reduce the demand for ammunition resupply, specialized rounds, and specialized MHE.

In addition to the warfighter's requirement for early-entry supplies, they and their combat equipment require resupply of consumables after initial insertion. OPTEMPO and combat platform consumption rates will dictate when and how often this resupply must occur in order to maintain a viable fighting force. The ability of the individual warfighter and small combat units to attain water and food on their own will significantly reduce the logistics footprint on the battlefield as well as the quantities of Class One supplies that would otherwise have to be deployed to the theater of operation.

The Water Purification Technology initiative seeks to reduce logistics needs by 25 percent, providing individual and small unit water on site.

Challenges

The challenge to providing mobile field services for kitchens, sanitation facilities, laundries, and space heating systems is the efficient cogeneration of heat and electric power by integrating fuel cells and thermophotovoltaic (TPV) generators. Clean, reliable diesel combustion, efficient heat transfer, safe methods for storing perishable subsistence, and modularity and integration of components are needed to support transportable kitchens for all environmental extremes.

3 Logistics Command and Control—Situational Understanding

Capabilities envisioned for the Objective Force and the associated concepts being advocated by the warfighters—early entry "fighting off the ramp," dispersed forces, high-speed movement over the battlespace, and a reduced logistics footprint in the battlespace—require logisticians to have both an increased awareness of battlespace conditions and the traditional knowledge of logistics assets and various classes of supplies.

Goals

Logistics command and control (Log C^2) requires total situational awareness of all classes of supply on a global basis while in storage, while in transit, and during distribution. The logisticians must have the communication assets to transmit and receive weapon system health status data. The shift in the logistics' paradigm from reactive to anticipatory depends on having the communications assets, as well as decision support tools required to translate awareness into under-

standing for decision-making. The Training Tools for Web-Based Collaborative Environment initiative supports the anytime/anywhere training paradigm.

Challenges

Challenges in this subarea are overcoming the global bandwidth constraints, development of onboard artificial intelligence for processing of system's health sensor data for subsequent transmission of impending component failures, and provision of affordable passive and semiactive RF tags with functional ranges compatible with operational requirements.

4 Logistics Demand Reduction—System Reliability

System reliability is a key factor in attaining the required force projection times, reducing the demand for logistics, decreasing life-cycle O&S costs, and meeting the stated requirements to reduce logistics footprint within the battlespace.

Goals

The two primary goals of this subarea are to develop and field new combat equipment whose components will not fail—other than due to enemy action—during the time of deployment and employment, and to reduce the O&S costs 20 percent by 2005 as directed by OSD. The Cannon Wear and Erosion initiative improves gun barrel life tenfold compared to current equivalent gun barrels.

Challenges

The challenge is to design, manufacture, and acquire new combat systems that do not fail—except as a result of enemy action—during their expected time of deployment and employment. The MTBF of components needs to be increased to a minimum number of hours commensurate with anticipated duration of deployments and employments while retaining the 90 percent fleet combat readiness. Many life-cycle failures can be avoided by designing out fault mechanisms such as vibration, erosion, and corrosion.

5 Logistics Demand Reduction—Prognostics

The Army relies on an essentially reactive business practice regarding weapon system degradation on the battlefield, using diagnostic equipment to determine faults and part failures after they have broken. Built-in, onboard, real-time prognostics provides a capability to change to a proactive business practice where weapon systems can predict in real time their impending failure and logisticians can respond prior to component failure.

Goals

Current technologies can provide warning of impending weapon system failures before they occur. Embedded sensors integrated with onboard artificial intelligence (AI) capabilities can predict failures and self-report them, avoiding costly collateral damage to other system components. Such a real-time prognostics capability can be designed and built into new systems or retrofitted to legacy systems. This would not only reduce LCCs significantly but also minimize the requirement for the extensive and varied test measurement and diagnostic equipment that currently has to be deployed with the weapon system. The POL Quality Analyzer and Sensors STO develops and demonstrates device(s) to diagnose mechanical problems and extend oil and lubricant life.

REMOTE READINESS ASSET PROGNOSTICS/DIAGNOSTICS SYSTEM (RRAPDS) STO (2000–02). This initiative remotely monitors health and condition and delivers advanced diagnostics and prognostics in missiles, ammunition, and launch platforms while assets are tactically deployed, in storage, or being transported, thereby allowing for condition-based maintenance. RRAPDS will demonstrate extremely small, low-cost microchip-based devices that can be embedded in munitions and related packaging to provide real-time information on the condition or "health" status of critical munitions. It will enable remote wireless tracking of expenditure rates and logistics data in support of anticipatory resupply. *Supports:* PM Patriot, PM Follow-On TOW, future missile systems.

Challenges

The technical challenges for built-in, real-time prognostics are the development of in situ labs-on-a-chip sensor technology, onboard AI such as neural networks, and the determination of impending failure patterns for system components.

6 Logistics Demand Reduction—Power and Energy

The most significant logistics challenge facing the Army is the distribution of power and energy on the battlefield. The advent of advanced weapon systems such as the FCS, high-energy weapons, and the Land Warrior and its many electronic devices increases power and energy needs. Reduction of hydrocarbon-based fuel consumption along with a reduced dependency on conventional batteries is a necessity if the warfighter is to be sustained with energy on the battlefield.

Goals

The Army is investing in power source technology programs to improve logistics functions and to make C^4 systems work. Commercial technologies are being modified and adapted to develop high-energy, cost-effective primary and rechargeable batteries. These batteries must be lightweight, environmentally benign, and suitable for both training and combat situations. With the emphasis on reduced weight and size, advanced medium-sized mobile power systems are being developed to satisfy the Army's need to achieve its "power on-the-move" and "rapid force projection" initiatives. The general design is based on the advancement and adaptation of state-of-the-art alternators, power electronics, diagnostic and prognostic technologies, and protection devices. Lightweight, liquid-fueled cell power sources in the 50- to 150-W range are being developed for use in a variety of soldier applications. The ultimate goal is to demonstrate a 150-W/5,000-Wh fuel cell power source weighing less than 5 kg by using the best available liquid-fueled proton exchange membrane technology.

The High-Energy, Cost-Effective Primary and Rechargeable Batteries STO program has the goal of providing a battery with energy content 20 percent greater than that of the existing nickel-metal hydride battery.

The Integrated Power Generation and Management Technologies STO program goals are to optimize battery capacitor hybrid size, weight, and cost; demonstrate optimized electrochemical technology on a 5-kW testbed; evolve a tool for system-level, low-power design; deliver hybrid and kinetic prototypes for field trials; demonstrate power OTM; and demonstrate reduced power consumption.

The Advanced Tactical Fuels and Lubricants STO program provides for improved POL that will reduce fuel consumption, reduce maintenance demands, improve durability of components, reduce maintenance costs by 25 percent, and increase fuel economy by 4 percent.

The Power Conversion Technology for FCS STO program is an enabling technology for hybrid and electric drive systems, which greatly improves fuel efficiency and thereby reduces the logistics footprint of the future Objective Force, reduces converter size by 60–75 percent, and reduces weight by 50 percent.

Challenges

Discovery through research of the next form of usable energy is required to eliminate the Army's dependency on hydrocarbon-based energy sources of today.

Technology Objectives

Table IV–12 presents the technical objectives for logistics.

TABLE IV–12. TECHNOLOGY OBJECTIVES FOR LOGISTICS

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Early Entry & Resupply	Demonstrate a 20- to 25-g airbag landing system that provides an all-weather, rapid roll-on/roll-off cargo airdrop capability Demonstrate a soft-landing capability that augments personnel parachute performance & reduces system descent rates to values below 16 ft/s using "pneumatic muscle" technologies Demonstrate a full-size cargo parachute that achieves a 20% reduction in weight, bulk, & manufacturing costs (compared to fielded parachutes) while providing equivalent flight performance Demonstrate ship-to-shore cargo transfer	Demonstrate the application of pneumatic muscle technology as a low-cost actuator in the precision control of the Container Delivery System Demonstrate semiballistic, high-altitude, high-speed container delivery capabilities using enhanced parachute designs & slider reefing techniques Demonstrate the application of pneumatic muscle technology as a soft-landing capability for heavy cargo airdrop Demonstrate ship-to-shore cargo transfer in sea state 4	Demonstrate autonomous, day/night, all-weather precision delivery of 10,000-lb minimum payload into vertically developed area Demonstrate advanced airdrop recovery/ stabilization technologies that reduce ground dispersion & personnel/equipment linkup times Demonstrate advanced airdrop predictive performance & design optimization modeling & virtual testing that reduce development, testing, & procurement costs Demonstrate unrestricted ship-to-shore cargo transfer
Logistics Demand Reduction—Resupply	Eliminate 10% of intermodal delays in shipment	Eliminate 50% of intermodal delays in shipment Develop modular "plug-in" munitions packaging that speeds resupply through the logistics system & rearm of the weapon system on the battlefield Develop an autonomous rearm & resupply system that is integrated with the FCS autoloader to reduce rearm time & manpower requirements by up to 67%	Eliminate 90% of intermodal delays in shipment Develop lightweight packaging materials that decrease visibility &, using nanotechnology, allow logistics monitoring to ensure just-in-time delivery of sustainment Develop interactive, highly functional components (smart foods) as specialized supplements active against short-term acute stresses; integrate performance-enhancing supplements with a personal status monitor
Logistics Command & Control—Situational Understanding	Eliminate the "sneaker net" Integrate Log C^2 systems	Demonstrate weapon system onboard, real-time, self-reporting diagnostics Demonstrate weapon system automated self-reporting of consumables, selected systems Demonstrate Log C^2 system fully integrated into Army C^2 architecture Demonstrate critical classes of supply items tagged & automatically tracked	Demonstrate weapon system onboard, real-time, self-reporting prognostics Demonstrate weapon system automated self-reporting of consumables Demonstrate seamless, global logistics command & control system Demonstrate electronic tagging & automatic tracking of all classes of supply
Logistics Demand Reduction—System Reliability		Design out failure nodes in family of FCS, Comanche, Crusader, & other new combat equipment through manufacturing processes, materials, or design criteria	Increase MTBFs of weapon system subcomponents such that they exceed projected deployment/employment times

TABLE IV–12. TECHNOLOGY OBJECTIVES FOR LOGISTICS (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Logistics Demand Reduction—Prognostics	Achieve 90% P_d of impending failures of RWV structural components Demonstrate a full-up 65 in^3 RRAPDS in laboratory environment with 5-yr life	Achieve 95% P_d of impending failures of RWV components Demonstrate a 4 in^3 RRAPDS in a real-time environment with 10-yr life	Achieve 98% P_d of impending failures of RWV components Demonstrate a <4 in^3 in RRAPDS operational >10 years with advanced prognostics
Logistics Demand Reduction—Power & Energy	Reduce energy resupply requirements by 5% Integrate generator with thermal fluid heat transfer technology & demonstrate high-efficiency cogeneration in a mobile field kitchen Demonstrate next-generation, low-cost, high-energy (>150 Wh/kg) primary Li batteries for man-portable equipment Demonstrate lighter weight, higher-energy-density (>80 Wh/kg) Li-ion rechargeable batteries Demonstrate improved spin-stable reserve batteries Demonstrate low-temperature (30 °C) electrolyte for Li batteries Demonstration new electrolytes for low-cost electrochemical capacitors Demonstrate components for man-portable 50- to 300-W hydrogen-fueled fuel cells for the Soldier System Demonstrate man-portable (40 lb/kW), signature-suppressed 3,000-W engine-driven generator set; the engine will have a brake-specific fuel consumption of 0.52 & thermal efficiency of 25% & will be capable of starting & operating on DF–2/JP–8 fuels Demonstrate DARPA-sponsored TPV power source	Reduce energy resupply requirements by 50% Design out energy demand on new combat equipment Demonstrate advanced cogenerator & waste utilization system based on fuel reformer & fuel cell Demonstrate high-energy-density (>250 Wh/kg) Li primary batteries Demonstrate high-energy-density (>250 Wh/kg) Li primary batteries Demonstrate low-cost electrochemical capacitors for electric vehicles Demonstrate fuel cell stacks that operate on liquid fuels Demonstrate/validate signature-suppressed, electronically controlled, man-portable & man-handleable 0.5- to 3.0-kW engine-driven generator sets that provide power OTM, enhance total asset visibility & CSS operations, & are compatible with emerging C^{4}I & weapon systems Continue demonstration of DARPA-sponsored TPV power source	Reduce energy resupply requirements by 75% Demonstrate FCS with 20% increase in fuel economy Integrate fuel cell & hydrogen-producing chemical heater with advanced shelf stable foods in an autonomous meal preparation & serving system Demonstrate rechargeable Li/polymer batteries with energy densities of >200 Wh/kg, low cost, improved safety, and good low-temperature performance Demonstrate new pouch primary combat battery (>250 Wh/kg) in flexible conformal packaging Demonstrate practical silent TPV power sources to 50-kW transportable fuel cells Demonstrate active batteries with very long shelf life for smart munitions Demonstrate battery/capacitor devices capable of full charge/discharge in minutes, with energy densities of >300 Wh/kg Demonstrate portable 5,000-W diesel-engine-driven generator set compatible with emerging C^{4}I and weapon systems Demonstrate dual-use electromechanical (power generation, transmission, distribution, or utilization) technologies & equipment (0.5–1,100 kW) that reduce system size, weight, & visual & audible IR signatures; improve system reliability; minimize O&S costs; & improve the deployability, tactical mobility, & effectiveness of a CONUS-based fighting force

M MATERIALS, MATERIAL PROCESSES, AND STRUCTURES

The Materials, Material Processes, and Structures technology area focuses on improvement and development of hardware and platforms for Army systems.

This technology area provides enabling Army-unique technology solutions and options that will significantly increase the level of lethality and survivability performance while improving mobility, transportability, and durability, and also reducing the logistics and maintenance burden and the overall life-cycle costs of most Army systems.

The Army's Manufacturing Technology (ManTech) program addresses defense-critical manufacturing processes to lower costs and improve the quality of the product. ManTech is working to create major shifts in the cost and speed with which military products are developed, produced, and repaired by benchmarking the best practices in the industrial world and fostering their widespread implementation. New manufacturing processes and systems and integrated product and process development capabilities developed by Army ManTech investments enable reductions in cycle times for new system acquisitions or for technology insertions into existing systems, permitting the fielding of today's technology. ManTech is investing in the development of manufacturing processes and capabilities to support defense-essential product technologies. The manufacturing technologies are covered in Annex G.

Meeting the performance needs of future Army systems requires the synthesis of new materials; modification and characterization of existing materials; design and fabrication of property-specific meso-, micro-, and nanostructures; and development of functionally integrated composite and hybrid architectures. Also required are the development of advanced compositional modeling and characterization techniques for both prediction and attainment of specific microstructures, properties, and both quasi-static and dynamic degradation and damage modes. Validated accelerated aging tests and life-service prediction models will provide Army stakeholders with life extension capabilities to better maintain currently fielded systems and to create more capable and durable future weapon systems. Improved materials are also needed for survivability in extreme environments such as CBW, high-velocity impacts, and extreme thermal hazards, including fires and explosions.

Technology Subareas

This technology area encompasses three technology subareas: Materials, Processes, and Structures.

MATERIALS, MATERIAL PROCESSES, AND STRUCTURES-RELATED STOs
Materials
Cannon Wear and Erosion
Metal Matrix Composites for Ordnance Applications
Processes
A Novel, Low-Cost Composite Armor and Army Vehicle Materiel Manufacturing Process

1 Materials

This subarea focuses on providing monolithic and combined materials with the superior properties required for use in platform structures, propulsion and power systems, armor and antiarmor systems, sensors and electronic systems, laser-hardened components, and various operational support systems as well as nondestructive evaluation. Many classes of materials are addressed, including metals, ceramics, polymers, composites of all types, coatings, energetic materials, semi- and superconductors, and electromagnetic functional materials.

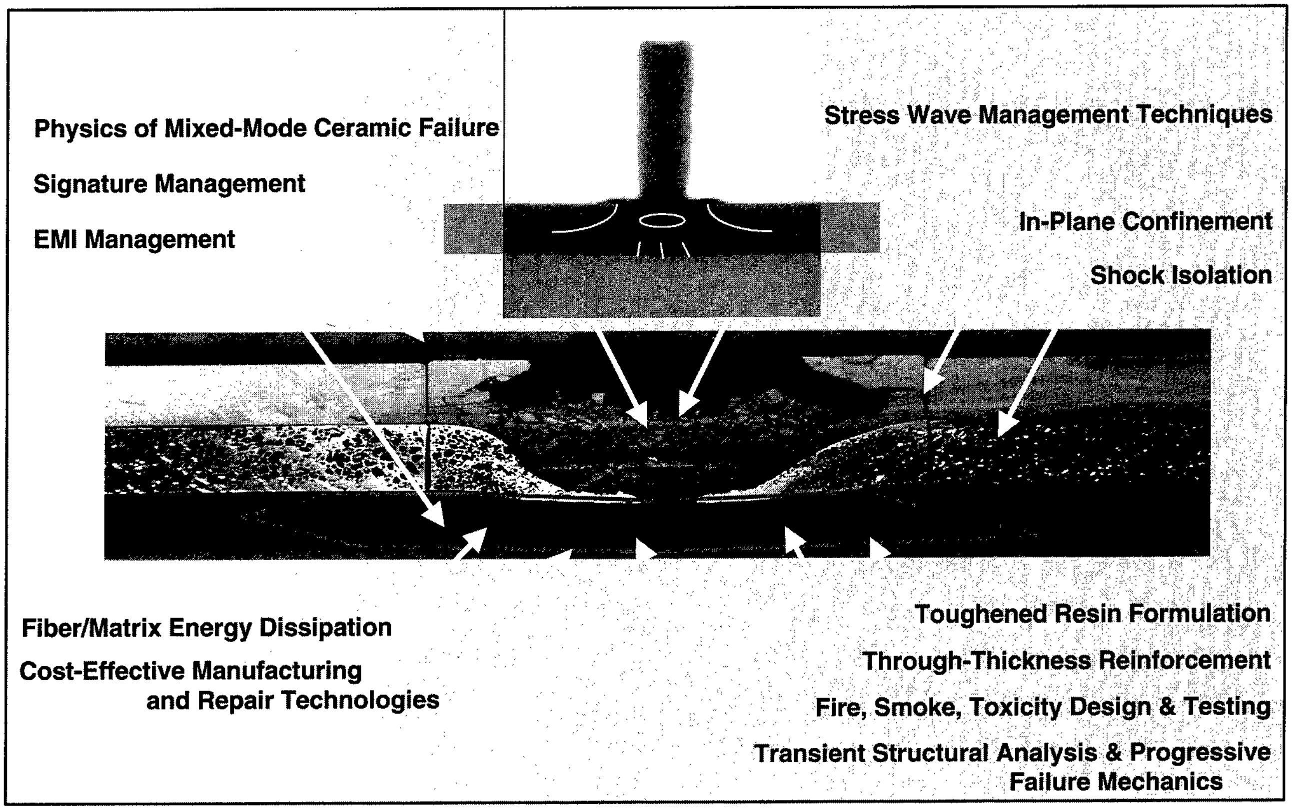
Goals

New materials with greatly improved properties and durability are being developed that enable major improvements for Army systems. For example, development of bulk, thick-film, and thin-film ferroelectric materials technology will enable payoffs in tactical and communication radars, including small size, light weight, multiband operation, fast response, low-drive voltages, and high-frequency operation at low cost. Thin-film ferroelectrics technology will also provide geometric flexibility required for conformal systems and smart munitions with direct integration into semiconductor devices.

Entirely new polymer matrix composite material concepts are being developed for reducing armor weight by 35–45 percent and significantly improving ballistic performance and reducing overall system costs. This weight reduction will enable significant increases in air deployment capability. Further opportunities arise from the integrated multifunctional capabilities of composite and hybrid material systems whereby structural, ballistic, and signature control improvements can be achieved simultaneously in one system (Figure IV–19). Advanced ceramics are under development for both opaque and transparent armor applications as well as for missile guidance domes and windows. Transparent armor ceramics and polymers are being further developed to demonstrate superior ballistic properties for soldier systems and ground vehicle applications. Transparent micro- and nanolayered polycarbonate/polymethyl merthacrylate composites are also being developed for lightweight transparent armor applications Encapsulated opaque ceramics under lateral and axial constraint are under investigation to improve their capability for interface defeat of high-velocity impacting projectiles.

By FY04, advanced armor ceramics with improved damage tolerance and penetration resistance with confinement will be demonstrated for larger scale projectiles at velocities above 2,000 m/s. Opaque, ultralight, ballistically resistant personnel protection materials are being further developed. Recent advances in converting highly ordered polymers into textile fibers with outstanding strength-to-weight ratios will lead to lighter weight body armor, helmets, and shelters without reducing ballistic protection. CAD and scientific visualization techniques for the molecular structure of polymers are being used to develop improved transparent armor and controlled permeability barrier materials for protection against CB agents. New classes of materials known as "functionally graded materials" are being developed. Combining the superior hardness and strength characteristics of ceramics with the structural properties of metals, these materials offer the promise of multihit capabilities not found in pure ceramics as well as lighter combat vehicle designs. Parallel efforts in high-speed numerical modeling of these new materials and their performance will allow vehicle designers design flexibility for optimal performance previously not possible.

A 50 percent improvement in barrier properties for chemical-agent-resistant polyurethane will be demonstrated, and an environmentally acceptable chemical agent coating with 100 percent



This X-ray photo shows a bullet striking a composite armor plate that is superimposed above the damage zone resulting from the impact. Arrows point to some of the material characteristics and physical responses involved in optimizing the armor response.

FIGURE IV–19. FLASH X-RAY OF A BULLET STRIKING A COMPOSITE ARMOR PLATE

reduction in hazardous air pollutants will be formulated. Materials optimization for in-service life extension includes the characterization and quantification of properties for off-road tires for future combat vehicle applications. Improved wear-resistant coatings and advanced composite materials with tailored combinations of mechanical and physical properties for reducing weight and improving durability of both conventional armaments and electric guns will be demonstrated by FY03. The Cannon Wear and Erosion (FY98-01) STO program will develop mitigating technologies for future highly lethal direct and indirect munitions delivered by medium- and large-caliber platforms. A tenfold improvement in barrel life will be demonstrated.

Challenges

Although the field of materials science has achieved dramatic advances in materials performance, many formidable scientific and technological problems of particular importance to the Army still remain. Among these is the ability to transfer the state-of-the-art knowledge base of composition-microstructure-property parameters to models that predict the behavior of materials in such complex phenomena as ballistic penetration and defeat, detonation kinetics, environmental degradation, and chemical agent permeation. Specific technical challenges include:

- Multilength-scale constitutive models to predict the static and dynamic behavior of polymer and inorganic matrix composites and hybrid material combinations.
- Predictive models for the environmental durability of monolithic and composite materials.

- Improved models for the interactions of gases, vapors, and liquids with polymeric barrier materials for CB protection.
- Opaque and transparent ceramic microstructures that will provide superior ballistic performance with improved mass and space efficiencies; and development of cost-efficient, lightweight, transparent armor ceramics and polymers for personnel and sensor protection.
- Integration of ferroelectric phase-shifter thin-film materials with silicon technology.
- Tungsten or other heavy metal alloys/microstructures that will provide ballistic performance equal to that of depleted uranium, and improvements over copper shaped-charge liners.
- High-strength steels and titanium alloys with improved ballistic properties that also maintain toughness, weldability, affordability, and stress-corrosion-cracking resistance for application to advanced combat systems.
- Improved materials for protection from agile laser threats for the individual soldier and for direct-view optics, and improved nonlinear optical materials for sensor protection devices.
- Reduced wear and erosion in structural and functional materials for armament and vehicle components.
- Modeling and mitigating the micromechanical failure mechanisms in elastomeric materials for tank track application.

2 Processes

Materials processing includes those technologies by which raw or precursor materials are transformed into affordable monolithic or engineered materials or components with the requisite properties and reliability for Army applications. Processing includes such technologies as casting, rolling, extrusion, cold and hot isostatic pressing, hot pressing, furnace sintering of metal or ceramic powders, laser sintering of titanium, polymerization, filament winding, composite processing and curing, joining, machining, and chemical vapor deposition. Also, lower substrate temperature coating processes are being developed, including ion-beam-assisted deposition, pulsed-laser deposition, and other surface modification technologies.

Process modeling and control and the development of new processing techniques for the manufacturing of multifunctional material systems will simultaneously improve the quality and reduce the cost of future Army materiel. Under the new paradigm of intelligent processing, quantitative process models, AI/expert systems, embedded sensors, intentionally inhomogeneous compositional and microstructural gradients for localized property modification, and feedback/feedforward control systems are coupled so that processes can be adjusted in real time. Closely allied to intelligent processing are online nondestructive testing and inspection technologies, which enhance quality and durability.

Goals

S&T program thrusts focus on those processes that are required to incorporate affordable advanced materials in Army systems. Thick-section composite processing presents unique challenges not encountered in traditionally thin structures. Process simulation models are required that couple the effects of thermochemical and thermomechanical interactions and incorporate micromechanical models to accommodate complex fiber and fabric architectures. New technologies—such as coinjection resin transfer molding (RTM), which provides improved properties while reducing manufacturing costs of multifunctional integrated armor systems—are under development.

Improved process control methodologies, including neural net feedback/feedforward capabilities and integration of the sensors mounted as roving thread weave processes, are being developed for transition into manufacturing systems. Processing thrusts to develop advanced composites and low-cost titanium alloys for lightweight armor and weapon systems (such as howitzers) with enhanced air mobility will be demonstrated by FY02. A laser-direct metal deposition process for rapid prototyping to near-shape, fully dense, large-scale titanium parts and structures is being developed. Lower temperature and lower cost ceramic processing approaches are being developed to improve the affordability and availability of advanced transparent and opaque armor ceramic materials. Candidate transparent armor ceramic materials being investigated include spinel, aluminum oxide, and sapphire. Novel barium strontium titanate (BST)-based ferroelectric materials are being developed for discrete and integrated microwave applications such as fire control radar, smart munitions, and point-to-point communications. Properties and tape casting process optimization for recently developed high-performance BST ferroelectric materials are being refined that will enable size, weight, and cost reductions for a new generation of microwave phased shifters operating at 35 GHz. This technology will be transitioned to CECOM in FY05.

Challenges

Much progress has been made in modeling single processes and process steps. However, the integration of real-time, noncontact, or online sensing (especially at the very high temperatures required in metal and ceramic processing) with adaptive control technology for the vast array of materials processes used by the Army is a formidable challenge. Specific challenges include:

- Knowledge-based models for consolidation synthesis, post-consolidation thermal or thermomechanical processing, and improved capability for joining or repair of polymers, ceramics, metals, and organic and inorganic matrix composites.
- Opaque and transparent ceramic processing techniques and models for significantly improved size scaleup, affordability, and impact damage tolerance.
- Characterization and consolidation processing techniques for nanoparticulate-size metallic and ceramic materials for projectile, warhead, and armor materials.
- Processing optimization and scaleup techniques for bulk, thick-film, and thin-film ferroelectric materials that provide maximum tunability and minimum loss at frequencies ≥ 35 GHz.
- Accelerated test methodologies of polymers and metals to predict service lifetimes in various aggressive environments that the Army encounters worldwide.
- Process optimization for nanosize organic materials for CB protection.
- Process-specific sensors and control systems.
- New materials processing or surface modification techniques to achieve near or actual net shape components with significantly improved tribological or structural performance in more affordable materials and in design systems.

3 Structures

The structures work is aimed at demonstrating generic structural concepts and technologies based on advanced materials and processes that meet Army-specific needs, such as structural elements for armored vehicles and helicopters, guns and ammunition, and missiles and smart projectiles. Of particular interest is the combination and integration of various materials for improved performance synergy as well as the development and modification of design tools and modeling for damage tolerance life prediction analysis. The multifunctional armor and vehicle structures technologies have direct application to the Army's "lightening the force" thrust and

are expected to impact all future generations of combat, tactical, and logistics wheeled vehicles as well as selective aircrew and personnel protection.

Goals

The structures technology subarea focuses on developing generic structural concepts and technology, with a high level of structural integrity, that are inspectable, analyzable, and survivable in the harsh combat environment. To be cost effective, the structural design must integrate advanced materials and structural design concepts that are compatible with mass production ManTech. These structures can be manned or unmanned air or ground vehicles that require challenging weight reduction for transportability while maintaining essential structural performance capabilities.

Technological efforts have led to improved methodologies for detecting and predicting the onset and growth of internal damage in composite structures. This has resulted in lighter weight, more durable structures. In the advanced concepts area, conceptual composite vehicle structures that integrate both ballistic protection and structural support are being developed and evaluated. Such integral composite structures offer significant improvements in weight and noise reduction, as well as the potential for integration of other multifunctional attributes. Additionally, composite structures in rotating pulsed-power systems provide distinct weight and other design advantages. The application of smart materials to control sound transmission through a structure has been demonstrated on fuselage-like shells fabricated from composite materials. Reducing interior noise levels greatly improves crew comfort and reduces occupant fatigue levels. In FY99, an effort began to develop the materials models required to evaluate potted electronics, servo-controls, and electronic power systems for maneuvering, competent munitions. These models are to be integrated into advanced dynamic structural simulations to assess their predictive capabilities.

Challenges

Challenges include:

- Develop new and improve the accuracy of existing materials modeling in ARL computational structural mechanics codes, and extend the range of materials that can be modeled.
- Design and prototype structurally efficient, cost-effective, and durable composite and hybrid structural concepts for transition to Army-unique air and ground vehicles and to other structural applications, including troop support and ordnance.
- Improve quantitative and nondestructive diagnostic techniques for defect detection, service, and battle damage assessment and prediction of continuing performance capability.
- Develop affordable in situ sensors for identification, quantification, and real-time condition monitoring of defects and anomalies in composite structures.
- Develop fracture mechanics methodologies and low-cycle fatigue and stress analyses suited to meet Army structural needs.

Technology Objectives

The technology objectives for Materials, Material Processes, and Structures are shown in Table IV–13.

TABLE IV–13. TECHNOLOGY OBJECTIVES FOR MATERIALS, MATERIAL PROCESSES, AND STRUCTURES

Technology Subarea Components	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Materials	Demonstrate processing/microstructure/property relationships for armor ceramics Characterize emerging projectile threat materials under dynamic loading Characterize amorphous composite penetrators Develop next-generation topical protective skin cream Develop nanoencapsulated enzymes for soldier protective clothing Demonstrate improved ballistic resistance of Ti casting Identify & characterize low-cost integral composites Demonstrate low-loss, high-tunability BST thin films & low-loss barrier layers for integration with Si technology	Develop constitutive models for organic & inorganic armor materials Develop ceramic thermal barrier coating for Army diesel propulsion Model threat material defeat by ultra-lightweight armor materials Transition next-generation TPS cream Demonstrate DU performance with amorphous penetrator materials Develop high-density refractory metal liners for 25% increased lethality of shaped-charge EFP warheads Develop environmentally benign long-rod material with 10% greater penetration Achieve 25% cost reduction in organic composite structures Optimize BST thin-film materials & transition bulk-phase shifter materials	Transition confined armor ceramics to user Validate full-scale micromechanical models for armor ceramics Transition nanoencapsulated enzymes for soldier protective clothing Transition tungsten shaped-charge liners Transition modeling tool for FGMs to TARDEC Develop high-temperature polymers (400°C) Transition thick- & thin-film microwave materials
Processes	Develop transparent armor prototype with 30% reduction in weight & thickness Demonstrate subscale V_{max} process for thick-section composite plates Develop 3D thru-thickness embedded sensor array for damage evaluation Demonstrate novel processing for refractory metal warhead liners Develop laser-processed Ti plate Develop improved high-velocity oxy fuel process coatings for gun tube wear & erosion Characterize next-generation domestic high-strength fibers relative to BMD baseline	Demonstrate transparent polycrystalline spinel scaleup Consolidate metal & ceramic nanopowders Demonstrate continuous process for insensitive explosives Demonstrate RTM processing with embedded sensors Demonstrate functionally graded materials processing approach for armor Demonstrate improved processing of 35-GHz materials for phased-array antennas Demonstrate affordable processing of advanced multifunctional integral armor Transition fiber characterization techniques to standard practices	Demonstrate transparent, low-cost AlON scaleup Demonstrate radiation & EM curing of large organic composites Demonstrate continuous process for insensitive propellants Achieve affordable rapid prototyping with both organic & inorganic materials
Structures	Develop computer models for structural & ballistic performance of complex composite systems Develop lightweight shelter with 10% multi-spectral performance improvement Develop cohesive zone model for dynamic delamination in GRP materials Demonstrate constitutive behavior of rocket propellants at interior ballistic rates Demonstrate lightweight composites concept for light infantry support weapons	Develop multifunctional armor for active protection, overhead, & mineblast Achieve FGM constitutive model integration for 3D modeling capability Develop pulsed-power storage device Develop case-bonded, gun-launched rocket motor designs Demonstrate high-strength, lightweight materials/concepts for leap-ahead direct support weapon systems	Develop composites with embedded actuators & active sound cancellation Develop controls & airframe for gun-launched projectiles Develop lightweight rail gun structures

N SENSORS AND ELECTRONICS

Sensor technology provides the "eyes and ears" for nearly all Army tactical and strategic weapon systems as well as the intelligence community. Sensors support effective battlefield decisionmaking and contribute to achieving the near- and long-term warfighting capabilities.

Sensors represent an increasing cost factor for weapon systems; accordingly, cost reduction is addressed in this program through a number of thrusts, including affordable integrated circuits (ICs); ultra-large, uncooled, and multicolor infrared focal plane arrays (FPAs); multifunction, multiwavelength lasers; common modules; shared apertures; computer modeling and simulation (M&S); and adaptive processing. Expected payoffs include a real-time missile avoidance module for the Future Combat System, a 50 percent reduction in the cost of imaging radars also supporting the FCS and IR search track sensors, a 10-to-1 improvement in thermal sensitivity of IR sensors, and reductions in weight, cost, and power. Sensors are integral and fundamental to achieving situational awareness throughout the battlefield to win the information war. Because of their pervasiveness, sensors have multiple-platform applications and are vital to the survivability of soldiers and weapon platforms on the battlefield.

Electronic technologies enable cutting-edge components such as lasers, FPAs for combat vehicle detection and targeting, displays, and photonic devices in battlefield weapons. Technology products include design, growth, processing, and characterization of materials and devices; development of subsystems to assess the FPAs that provide imaging detectors and readout circuits for UV through the far IR; and integration of sensor systems. These technologies feed flat-panel, color, low-power, direct-view displays and enable other sensors technologies such as radar, EO, acoustic, magnetic, and seismic sensors. Automated target recognition (ATR), expressed in algorithms for target identification and detection and integrated platform electronics, is also addressed here.

Current applied research programs lay the foundations for future technology demonstrations. By providing critically required military capabilities—detailing troop positions, target locations, and battlefield conditions—both sensors and electronics technologies enable an array of subsystems on Army platforms. Flexible, robust sensor systems have significantly increased Army warfighting capabilities and have become a true force multiplier. Sensor technologies depend on research provided by the ARO, RDECs, ARL, contractors, and federated laboratory partners. In the discussion that follows, only some of the key objectives of the sensors and electronics area are included.

Technology Subareas

The Sensors and Electronics area is divided into two technology subareas. The Sensors subarea has four subsections: radar sensors; electro-optic sensors; acoustic, magnetic, and seismic sensors; and automatic target recognition. The Electronics subarea has eight subsections: millimeter-wave (MMW) components, smart high-resolution displays, photonics, solid-state lasers, focal plane arrays, microelectronics, electronics materials, and integrated platform electronics.

SENSORS AND ELECTRONICS-RELATED STOs
Sensors
Multifunction RF Sensor Technology
Near-Infrared Sensors
Advanced Acoustic/Seismic Systems
Advanced Signature Management and Deception
Warrior Extended Battlespace Sensors
Spectral/Spatial Data Exploitation for Terrain Categorization and Target Identification
Integrated Sensor Modeling and Simulation
Third Generation IR Imaging Technology
Electronics
Low-Power Display Components
Micro-Eyesafe, Solid-State Laser Sources
Advanced Focal Plane Array Technology
Low-Cost, Electronically Scanned Antenna
Sensor Optoelectronic Processing

1 Sensors

Detection, precise location, identification, acquisition, and tracking of targets and accurate situation awareness and damage assessment are key sensor elements for battlefield supremacy.

a *Radar Sensors*

Radar is the sensor for all-weather detection of air, ground, and subsurface targets. This subarea includes technology developments involving enhanced and new capabilities associated with wide-area surveillance radars, tactical reconnaissance radars, and airborne and ground fire control radars (FCRs).

Goals

One objective includes developing the technology underpinnings of ultra-wideband (UWB) radar technology for the detection of concealed stationary tactical vehicles and subsurface targets from airborne and vehicle-mounted platforms. Potential applications of this technology include detection of vehicles concealed by foliage or camouflage, countermine and humanitarian demining operations, and the detection of unexploded ordnance for survivability and environmental remediation. Another paramount objective of this technology area is the R&D of affordable FCR technology. This research offers the potential to enhance the ability of real-aperture radar to detect, track, and classify high-value stationary and moving targets for the Longbow Apache and Comanche programs as well as for vehicle-based systems such as the moving target indication (MTI) and imaging ground radar (MGR).

Challenges

Challenges include building an understanding of low-frequency, wideband target and clutter physics in varying environments; establishing and validating signal processing algorithms required to produce low-artifact synthetic aperture radar (SAR) imagery; developing and analyzing low-cost, lightweight, multifunction radar components; and developing innovative,

robust algorithms that support the detection and classification of stationary and moving targets with low false-alarm rates. Some of the specific challenges include:

- Real beam on-the-move (OTM) targeting for stationary ground targets.
- Removal of competing low-frequency RF interference signals in UWB radar data.
- Precision motion compensation techniques for low-artifact radar imaging.
- Detection of plastic mines in varying soil conditions.
- Enhanced spatial resolution for operational radar.
- MMW E-scan antennas.
- Affordability by design.

b *Electro-Optic Sensors*

Electro-optic materials (materials that use photons as well as electrons) are the cornerstones for the development of EO systems that provide military capabilities and warfighting options that cannot be achieved by other means.

Goals

Goals for EO materials research are to develop materials, fabrication processes, and device structures that are not supported commercially, but are necessary for developing Army microelectronics and EO devices and components. These materials need to be affordable with high performance for use in DoD systems. New, sophisticated EO materials will feed into EO devices that offer lighter weight, smaller volume per function, higher data rate processing, higher frequency and bandwidth operation, lower cooling requirements, and higher maintainability. Goals also include achieving a better understanding of the physical phenomena that govern laser performance of EO semiconductors such as the III–V gallium arsenide (GaAs) and solid-state materials (e.g., rare earths in yttrium aluminum garnet), detector performance, and other devices that rely on photon–electron interactions. Further, the goals include increased power and tunability of IR sources, nonlinear optical (NLO) devices for sensor protection, and uncooled IR FPA materials and devices.

Challenges

Most EO material needs to reduce the concentration of deleterious defects and control material composition, structure, and morphology to tailor and optimize the properties of the material. Applied research is needed to develop fabrication and characterization methods that yield high-quality materials at affordable prices.

The near-term challenge for wide-bandgap (high operating temperature) semiconductors, for example, is to produce material suitable for demonstration devices and small-scale components. Substrates that match the lattice constants and thermal expansion coefficients of III–V are especially important for good epitaxial growth. For the more mature GaAs- and indium phosphide (InP)-based semiconductor materials, challenges include fabrication of larger diameter substrates having lower defect densities, higher uniformity, and lower cost.

Key technical challenges for IR detector materials are the achievement of greater uniformity, more precise process control, and, for heterostructure detectors, control of interfaces and strain.

c *Acoustic, Magnetic, and Seismic Sensors*

Acoustic and seismic sensors provide accurate, very low-cost, non-line-of-sight target detection and identification capabilities for U.S. soldiers. The low-cost nature of the technology holds the promise of allowing individual soldiers to have acoustic sensors for self-protection and targeting.

Goals

Targets of interest include ground vehicles (both wheeled and tracked); fixed-wing aircraft and helicopters; personnel; and impulsive events such as gunfire, artillery fire, and rocket launches. Passive acoustic medical monitor sensors are also being investigated to facilitate combat casualty care and medical monitoring. Acoustic and seismic sensor attributes include low false-alarm rate, high P_d, and robust operation in the complex battlefield environment. Improved beamforming techniques with improved target bearing accuracy and high probability of identification, multiple target tracking algorithms, multiple target identification, and a robust database for target identification are important areas for investigation.

Although magnetic sensors hold great promise for short-range, low-cost detection of personnel and vehicles, little work has been done to date in the Army S&T program. Investigations into using magnetic sensors in conjunction with acoustic and seismic sensors began in FY00.

Challenges

Technical obstacles to be overcome include the following:

- Robust detection and direction finding on impulsive targets such as gunfire, artillery fire, and rocket launches; and continuous targets such as ground vehicles and aircraft.
- Accurate and robust target identification algorithms.
- Rejection of false alarms.
- Noise cancellation and wind noise alleviation.
- Sensor fusion.
- M&S of atmospheric and terrain effects.
- Understanding of sensor performance and compensating for real-world conditions.
- Robust database and algorithm evaluation infrastructure.

d *Automatic Target Recognition*

Technology areas that are integral to ATR include processors, algorithms, and ATR development tools, which include M&S. ATR systems will provide sensors with the capability to recognize and identify targets under real-world battlefield conditions.

Just as sensor systems are the "eyes" for tactical and strategic weapon systems, ATR systems provide the "brains" for these weapon systems. ATR systems and technologies will allow weapon systems to automatically identify targets to increase lethality and survivability; reduce the cost and ballistics burden of employing advanced, high-priced weapons; and reduce the cost and tragedy of losses from friendly fire.

Goals

In the near term, the Army's goals in ATR are to recognize 10 target classes with identification rates nearing 80 to 85 percent and significantly reduced false-alarm rates. Additionally, new algorithms will be developed for target identification cueing based on cues received from uncooled and short-wavelength infrared (SWIR) data collected. Mid-term goals are to recognize 20 target classes with improved detection and false-alarm rates. In the far term, ATR systems will use rapid training with minimal data to additionally improve performance.

Challenges

Today, the focus is on both single-sensor and multiple-sensor ATR algorithm development. While processor development is being successfully leveraged off the highly competitive commercial market, the importance of development tools remains high. Single- and multiple-sensor algorithm development programs are key to successful development of ATR systems for the Army. Ongoing hybrid data-driven, model-based algorithm development programs are providing exciting results that include detection rates approaching 100 percent, identification rates in the 85 percent range, and significant reductions in false alarms for moderate- to low-clutter levels.

2 Electronics

Research in microelectronics, device technologies, and similar material technologies will enhance development of very high-speed data processing and advanced control functions and devices in a variety of military systems. In addition, electronics is the basic technology of displays, which are crucial for all man-in-the-loop (MITL) systems. Detection, precise location, identification, and tracking of targets and accurate situation awareness and damage assessment are key elements for battlefield supremacy. Electron devices offer advanced technical solutions to these problems and can provide EO countermeasures and counter-countermeasures capabilities.

The Army electronics research program generates cutting-edge components essential for vital target detection and identification as well as communications on the battlefield. It includes design, growth, processing, and characterization of materials and devices; development of subsystems to assess the utility and performance of these devices; focused R&D and design of electronics materials; nanoelectronic devices (including digital, analog, microwave, and optoelectronic (OE) sensors and circuits); electronic modules, assemblies, and subsystems; and required portable power sources.

A versatile, innovative program in electronic device S&T is essential to the broad Army vision of (1) decisive force multiplication with a minimum number of platforms and personnel, (2) avoidance of potentially disastrous technological surprise on the battlefield, and (3) complete situational awareness on the battlefield. Power on the battlefield is a cornerstone of force effectiveness. Requirements of Army systems such as EW, radar, and C^4I translate into component requirements, which may include performance, weight, size, radiation hardness, interoperability, cooling, power consumption, maintainability, and survivability. This technology area represents more than 40 percent of the procurement cost of many military systems. Military purchases of semiconductor electronics have increased annually. Semiconductor electronics was one of very few areas to experience significant growth. Fielding of weapon systems that meet present requirements, that can be upgraded to meet future requirements, and that have affordable LCCs

will demand exploitation of commercial electronics whenever possible, plus development of the special technologies for Army systems that need unique capabilities.

Electro-optic technology offers advanced technology solutions to the problems of high-resolution target location and identification, nighttime surveillance, and high-capacity data storage and processing. In addition, EO is the basic technology of displays, which are crucial to all MITL systems. The continued development of high-performance MITL and autonomous systems using advanced EO technology will substantially advance global surveillance and communications, and all-weather, day/night, camouflage-resistant precision strike missions against fixed and mobile targets. Photonics will provide high-capacity, rapid-access data storage; distortionless wideband analog fiber-optic communications for sensor, emitter, and antenna remoting; ultra-high-speed data processing for real-time analysis of SIGINT and ELINT data; and new approaches to steering and control of microwave beams. Cost reductions in IR FPAs will be sought through uncooled sensor technology and improvements in the functionality of cooled IR FPA technology. New applications will be addressed through development of multispectral sensors. Laser technology will attempt to lower the cost per watt of semiconductor lasers, develop long-lived blue laser diodes, and demonstrate eye-safe tunable monomode fiber-optic lasers. Long-term (FY01–05) goals include integration of IR FPA and ATR functions, 3D stereoscopic displays, and monolithic OE integration leading to 2D optical "smart" pixel arrays for high-speed parallel processors.

a *Millimeter-Wave Components*

The four technology thrusts of the MMW components program are solid-state electronics, vacuum electronics, signal and frequency control, and antennas.

Goals

Program objectives include development of vacuum electronic devices and related components and material technologies to meet Army system insertion needs; development of ultrastable, low-noise frequency sources, digital synthesizers, and clocks for systems; and development of supporting and enabling technology for low-cost, shared-aperture, multifunction antennas with advanced transmit/receive (T/R) functionality, digital beamforming capabilities, and conformal and reconfigurable agile arrays. Goals include developing advanced RF, optical, and digital components for fully integrated, multifunction radar, EW, and communications compact sensors.

Challenges

Technical challenges to the MMW components program include the development of low-cost, ultrastable, low-noise frequency sources, digital synthesizers, and clocks for systems; and the development of supporting and enabling technology for fully integrated low-cost, shared-aperture, multifunction antennas with advanced T/R functionality, digital beamforming capabilities, and conformal and reconfigurable agile arrays.

b *Smart High-Resolution Displays*

Display technology will address the problems of developing high-definition helmet-mounted displays (HMDs) for the individual soldier and the aircrews.

The first category includes HMDs, rifle-mounted displays, and handheld, see-through, and high-luminance displays for use in the Comanche and for future upgrades to the M1A2. These devices need to be compatible with harsh military environments.

The second category includes rugged, large displays with reduced footprint, direct view and displays, and very high-resolution displays for the commanders overseeing the battlefield.

The third category includes displays that have good environmental characteristics and are low power for man-portable applications. These displays are small to medium size and run the gamut from low- to high-information content.

Goals

The smart high-resolution displays program has three major goals: (1) miniature, low-power, lightweight, rugged, flat-panel devices for the individual soldier, ground, and aviation platforms; (2) large, high-information-content color displays for battlefield situational awareness; and (3) low-power, direct-view displays. The Low-Power Display Components STO program will reduce the number of batteries by reducing power consumption by more than 50 percent.

Challenges

For the HMD, the challenges are improved resolution with color, reduced power, improved efficiency, increased luminance for high-ambient conditions, increased dimming range for low-light-level operation compatibility, and increased gray scales to match sensor resolution. For the large displays, the challenges are to reduce the volume and footprint (flat panel), reduce the weight, and provide more ruggedness. For man-portable, direct-view displays, the challenges are environmental characteristics and power efficiency.

c *Photonics*

The Army photonics program involves the use of combinations of photonic and electronic interactions in OE components to perform functions that are expected to contribute substantially to leap-ahead functional capabilities on the Army battlefield of the future. An essential extension of the basic material and component objectives of the program is to use this applied research to develop means of hybrid and monolithic integration and packaging of individual photonic components into higher levels of integration specific to Army applications. Photonics technology has a large impact in diverse Army functional applications such as communications OTM, laser rangefinding, laser designators, OE identification friend or foe, photonic control of RF, and high-performance OE processing in support of SAR, ATR, and image processing. It also has a large impact on OE sensors such as 3D LADAR, smart adaptive IR imaging, fiber gyro-rotational-rate sensing, OE CB sensors, and OE acoustic and magnetic sensors.

Goals

Near-term photonics activities are addressing polymer-integrated optics, III–V semiconductor heterostructures, and the emerging wide-bandgap semiconductors as promising and rapidly advancing OE photonic material systems. Advances in the state of the art in lasers, modulators, detectors, interconnects, and other photonic devices are needed to successfully insert OE photonic technology into Army systems. Mid-term goals include a growing emphasis on the integration and packaging of multiple OE photonic elements into higher levels of functionality that are compact, cost-effective, and manufacturable. Both hybrid and monolithic integration

techniques will be used to demonstrate feasibility. Use of strain effects and new heterostructure compositions will provide new photonic functionality. Capitalization on emerging commercial markets for photonic OEIC is an essential part of the affordable development of OEIC for Army applications.

Long-term Army photonics goals involve successful customizing of OEIC functionality to specific Army applications. The integration of electronic functionality with photonic functionality will provide higher levels of smart sensing, processing, and synergistic enhancement of the existing photonic and electronic capabilities. Intimate mixing of electronic and photonic functionality will lead to new capabilities and architectures not previously possible with isolated electronic and photonic components. New photonic semiconductor and polymer heterostructures will be incorporated into separate photonic components and OEIC.

Challenges

The Army faces a broad range of technical challenges in the development of photonics. Particularly pressing challenges include:

- Use of strain effects in semiconductor heterostructures to enhance and tailor OE performance.
- New semiconductor heterostructures for new photonic functionality.
- Hybrid and monolithic integration of multiple photonic and electronic functions.
- Integration of vertical cavity surface emitting lasers (VCSELs), detectors, and complementary metal oxide semiconductors (CMOSs) for OE interconnects.
- Alleviation of fundamental limitations in wide-bandgap OE material capabilities.
- Development of a polymer photonic material system with monolithic integration.
- Nonlinear OE materials optimized for limited protection of OE sensors.
- Optical readout of CB sensors.
- Optical microelectromechanical systems (MEMS) for battlefield sensors.

d *Solid-State Lasers*

The objective of the high-energy laser (HEL) program subarea is to develop the critical enabling technologies for HEL weapons to be more effective on the battlefield. This requires investment in solid-state lasers (SSLs), beam control and directing technologies, propagation effects, atmospheric compensation technologies, and threat lethality assessments.

Goals

The program goals are to develop 15- and 100-kW SSL demonstrators by 2002 and 2007, respectively, that show the necessary lethality for battlefield applications at reduced volume, improved reliability, increased energy efficiency, and lower logistical burden relative to conventional HEL weapon technologies. The long-term goal transitions the resulting technologies to prototype HEL weapons for use in field exercises.

Challenges

The primary challenge is to develop the heat management and affordable diode-pump array technologies that make SSLs attractive to the Army as an effective, low-cost-per-kill, low-logistics, and mobile weapon system.

e *Focal Plane Arrays*

The EO FPA program is working to provide imaging detectors and readout circuits for sensing in spectral regions from the UV through the far IR, and to integrate them into sensor systems. The sensor systems should demonstrate an enhanced capability for reconnaissance, surveillance, target acquisition, and maneuver in all battlefield environments. The imaging sensors will embody high-performance, cooled FPAs as well as lower performance (but lightweight and low-cost) uncooled FPAs.

Goals

Near-term goals include the development of two-color (within band) FPAs, dual-color mid-wavelength infrared (MWIR)/long-wavelength infrared (LWIR) FPAs, and uncooled FPAs with a noise-equivalent delta temperature (NEDT) less than 10 milli-Kelvin (mK). Mid-term goals include the development of large (up to $1{,}000 \times 2{,}000$) hyperspectral and multicolor (SWIR/MWIR/LWIR) FPAs with an operating temperature around 120 K.

Mid-term goals for uncooled LWIR FPAs include large (640×480) array size and small pixels (25 μm) and integration with uncooled short-wave detectors. Also, microminiature sensors are being developed that weigh less than 2 ounces and use less than 20 mW of power. These sensors will be used for micro-UAVs, robotic platforms, and unattended, short-range surveillance.

Long-term goals include the integration of a LADAR receiver into the multicolor FPA and the development of IR goggles. Other goals include microsensors that weigh less than 10 grams and consume less than 1 mW of power.

Challenges

Development of megapixel arrays presents challenges in uniformity and yield. Also, the multispectral capability and the placement of the active receiver on the focal plane will require development of advanced readout circuits with increased complexity and charge-handling capacity. Increasing the temperature of operation to 120 K will require additional advancements in materials. The active component of the sensor will require a compact SSL source and a laser demodulator for real-time image processing. Other challenges are to make it small, lightweight, low in power requirements, and low in cost, and to ensure that does not impose a design burden on the weapon platform. Specific challenges include:

- Gated SWIR imaging tube with CMOS sensor for active imaging applications.
- Low-cost, high-resolution uncooled FPAs (640×480).
- Monolithic integration of detector arrays on Si.
- Networked microsensors.
- Integration of smart functions onto focal plane readout circuits.
- Large-area FPAs.
- Multicolor (two or more bands) FPAs.
- Active polarization sensors.
- Development of hyperspectral filters.
- Integration of LADAR receivers with FPAs.
- Low-light-level, solid-state detectors.
- Miniaturization of IR cameras to 1 cubic inch.

f *Microelectronics*

The United States must maintain its military superiority in an era of rapidly changing microelectronics technology. This superiority is based on (1) force multiplication through advanced microelectronics (technology and component applications) with a minimum number of platforms and personnel, and (2) active avoidance of technological surprise in future combat scenarios. In this context, the microelectronics subarea develops device, circuit, and fabrication technologies to realize digital, analog, and mixed-signal ICs that are needed for introduction in a timely and planned fashion into weapon systems, ensuring superiority over our adversaries.

Goals

Specific goals of the microelectronics program are to:

- Develop techniques to integrate 100,000 transistors and 1,000 sensing/actuating elements in MEMS devices.
- Develop an integrated inertial guidance system on a chip.
- Develop an ultra-low-power (<1 mW), 16- to 18-bit, 2- to 100-kilo-samples-per-second, analog-to-digital converter for an unattended, remotely deployable sonar.
- Develop highly integrated, nanometer-feature-size, MEMS-based microsystems that integrate sensors, processing circuits, and input/output actuators and displays that are produced by affordable, flexible fabrication techniques.

Challenges

The warfighter's needs and projected threats are translated into technology goals aimed at removing bottlenecks and barriers to affordable collection and processing of information. As the commercial microelectronics market has experienced explosive growth, industry has focused increasingly on large commercial markets and less on critical military characteristics (e.g., radiation hardness, multi-gigahertz operation, and MEMS capability). It is now even more important that DoD surmount these challenges by (1) developing M&S mixed analog and digital circuits with greater bandwidths at multi-GHz clock rates, and (2) reducing MEMS fabrication complexity to lower the cost of fabricating MEMS products.

g *Electronics Materials*

The electronics materials subarea develops materials, fabrication processes, and device structures that are not supported commercially; are necessary for developing RF, microelectronics, and EO devices and components; and combine affordability with high performance for use in Army systems. Materials development supports device development thrusts by providing quick turnaround of materials growth and characterization; providing the ability to tailor growth and processing techniques to optimize parameters; and developing processing materials and techniques. Materials classes of interest include semiconductor, superconductor, ferro/ferrimagnetic, ferroelectric, and NLO materials.

Goals

In the near term, the goals are to advance metal organic molecular beam epitaxy and metal organic chemical vapor deposition single-wafer deposition technology, develop SiC process technology for high-temperature electronics and power devices, and develop ferroelectric film for nonvolatile memory applications. The mid-term goals are to develop reliable sources of InP wafers, achieve heteroepitaxial growth of device-quality GaAs on Si, and develop wide-bandgap

SiC devices for high-temperature and high-power applications. The long-range goals are to develop GaN materials and devices and develop accelerometers.

Challenges

Most electronics materials efforts are linked by the need to reduce the concentration of deleterious defects; control material composition (including intentional, judicious introduction of impurities), structure, and morphology in order to tailor properties; and develop fabrication and characterization methods that result in high-quality materials at affordable prices.

Additional challenges depend on specific materials and maturity of the technology. Substrates that match the lattice constants and thermal expansion coefficients of III–N films are especially needed. For the more nearly mature GaAs- and InP-based materials, challenges include fabrication of larger diameter substrates having reduced defect densities, higher uniformity, and lower cost; further control and exploitation of the relationships between growth environments and resulting properties—particularly controlling heterostructure interfaces such as InGaAs/InP and minimizing the strain induced by lattice mismatches between heterojunction constituents.

Key technical challenges for IR detector materials are achievement of greater uniformity, more precise process control, and, for heterostructure detectors, control of interfaces and strain.

h *Integrated Platform Electronics*

Integrated platform electronics focus on the integration technologies, disciplines, standards, tools, and components to physically and functionally integrate and fully exploit electronic systems onboard airborne (helicopter, remotely-piloted vehicle, and fixed wing), ground, and human platforms.

Goals

The goal is to reduce the cost and weight of conventional platform electronics by 50 percent while providing virtually 100 percent of platform mission capability.

Challenges

Technical challenges include determining an architecture or set of architectures that prove sufficiently robust to readily accept technology innovations developed in the commercial sector; improving reliability to reduce logistics, deployability, and support costs; and developing standardized image compression techniques and architectures to permit transfer of images with sufficient clarity and update rates to support digitization of the battlefield.

Technology Objectives

The technology objectives for Sensors and Electronics are shown in Table IV–14.

TABLE IV–14. TECHNOLOGY OBJECTIVES FOR SENSORS AND ELECTRONICS

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY 09–16
		SENSORS	
Radar Sensors	Develop COTS processor for target acquisition Complete Ka-band database of targets & clutter Develop Ka-band polarimetric monopulse radar testbed Develop algorithms for SHORAD	Demonstrate midfrequency radar for tactical UAV Insert stationary target indicator algorithm in MGR Demonstrate FOPEN SAR on a UAV—all-weather, wide-area detection of targets in foliage Reduce antenna size requirement by 50%	Demonstrate fully integrated wideband digital receiver for battlefield radar Demonstrate UWB GPEN capabilities against distributed targets
Electro-Optic Sensors	Increase power/tunability of IR sources Develop efficient nonlinear materials for visible wavelength conversion & sensor protection Improve fabrication techniques to create laser protective visors Determine chemical, structural, & electronic properties of dual-band IR detectors Develop advanced III–V ternary & quaternary EO heterostructures Determine carrier lifetimes in InGaAs quantum wells for VCSELs	Establish matured technology base in the synthesis & characterization of EO materials Develop efficient laser sources in the far-IR region for CB detection Develop NLO devices for sensor protection Develop efficient laser source at 3–5 μm Develop eye-safe micro SSLs Determine upper state quantum well carrier lifetimes for intersubband laser modeling Achieve long-life, UV laser diode operation at room temperature	Develop broadband, low-cost, low-loss, IR/visible, passive sensor protection using NLO materials Develop portable, high-power, tunable (UV to far IR) laser source for multiple applications Develop high-temperature IR detectors & lasers
Acoustic, Magnetic, & Seismic Sensors	Develop improved multiple target detection, tracking, & classification algorithms Evaluate acoustic medical sensors Develop acoustic algorithm development/evaluation laboratory Develop improved beamforming algorithms Develop environmental characterization & compensation Develop noise cancellation techniques Combine magnetic sensor with acoustic & seismic sensor	Develop enhanced hearing technology for soldier Develop long-range artillery & rocket location technology Investigate widely dispersed sensor concepts Investigate approaches to enhance sensor fusion & communication link performance Demonstrate acoustic sensors with embedded meteorological sensors Improve tactical decision aids Develop acoustic sensor M&S for atmospheric & terrain effects	Develop wind & vehicle noise reduction techniques Integrate weather models into acoustic sensors Develop advanced acoustic imaging techniques Demonstrate artillery-delivered acoustic sensor Reduce acoustic sensor size & weight Develop tactical communication link for acoustic sensors
Automatic Target Recognition	Develop multisensor ATRs providing 80% open target recognition Achieve 6X search rate Identify 10 target classes	Develop multisensor ATRs providing 90% recognition of ground targets in moderate to high clutter with acceptable false alarms Achieve 60X search rate Identify 20 target classes	Develop multisensor ATRs providing 95–97% recognition with acceptable false alarms Achieve 1000X search rate Achieve ATR with rapid training on minimal data
		ELECTRONICS	
Millimeter-Wave Components	Achieve continuous increases in single radar-type function (amplifiers, oscillators, mixers, switches) chips in the 1- to 140-GHz range Reduce cost of chips Demonstrate Ka-band power amplifier for missile seekers Develop broadband sub-MMW amps for advanced weapon systems	Develop microwave/digital ICs Develop microwave/optical ICs Develop MMW wireless communications Develop high-density 3D packaging Develop high-power vacuum devices Develop high-efficiency MMW power modules	Achieve full integration of MMICs with digital & OE devices in the 100- to 200-GHz range Extend sources to terahertz & IR spectral regions
Smart High-Resolution Displays	Develop high-resolution, full-color, flat-panel displays for tactical environments Develop miniature low-power, ruggedized displays for HMD applications (0.5 W for dismounted soldier) Improve 1,000- × 1,000-line HMD, 640 × 480, & RS–170 miniature displays	Develop miniature high-resolution displays for telepresence & VE applications Develop high-brightness HMD for cockpit applications Develop 1,280 × 1,024 color display for the soldier with <25 W Develop 2,000 × 1,000 color HMD to match improved detector resolution	Develop real-time volumetric (3D) full immersion displays Develop interactive displays Develop 2,560 × 2,048 color HMD

TABLE IV–14. TECHNOLOGY OBJECTIVES FOR SENSORS AND ELECTRONICS (CONT'D)

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY 09–16
ELECTRONICS (CONT'D)			
Photonics	Develop VCSEL/CMOS optical interconnects with hybrid electronic integration Develop improved NLO limiter materials Develop OE control of RF arrays Develop polymer waveguide OEIC Develop semiconductor waveguide OEIC Develop photonic CB sensor Develop optical MEMS acoustic & magnetic sensors	Develop VCSEL optical interconnects in OE processors Develop optical interconnects in cooled IR FPA Develop NLO device protection for OE sensors Develop OEIC controls for RF arrays Develop polymer/semiconductor waveguide OEIC for fiber gyro Develop OEIC CB multithreat sensor Develop fiber-coupled optical MEMS acoustic & magnetic sensors	Develop massive OEIC optical interconnects in new OE processor architectures for ATR, SAR, & image processing Develop wavelength diversity NLO device protection for OE sensors Develop compact, affordable OEIC controls for RF arrays Develop compact, low-cost manufacturable OEIC for three-axis fiber gyro Develop small, portable, affordable OEIC for CB multisensor Develop covert fiber-coupled networked arrays of optical MEMS acoustic & magnetic sensors for smart mines
Solid-State Lasers	Develop more efficient passive Q-switching for eye-safe lasers Develop low-cost, lightweight eye-safe microlasers Optimize frequency shifting techniques to provide 8- to 12-μm sources	Optimize eye-safe laser sources for ultra-lightweight LADAR & remote sensing Develop efficient laser sources for 3- to 5-μm & 8- to 12-μm regions	Develop portable, tunable countermeasure source Develop very lightweight, multispectral laser source for multiple functions
Focal Plane Arrays	Develop uncooled FPA with NEDT <0.01 °C for F/1 system Develop quantum well arrays with operating temperature >80 K Develop dual-color, 640 × 480 FPAs Develop range gate FPAs Develop networked microsensors	Develop fusion of multiple wideband sensors Develop 2,000 × 1,000 dual-color FPAs Develop 3D laser imaging FPAs Develop uncooled LWIR & SWIR large-area FPAs Develop 1,000 × 1,000 uncooled FPAs Develop smart, multicolor FPA producibility with image processing functions Develop microsensors <2 ounces & <20 mW of power	Develop monolithic, multifunction, multispectral (>2), active/passive (including LADAR) smart FPAs Develop microsensors <10 grams & <1 mW of power for microrobotics operations Develop far-IR goggles Develop all-weather FPAs
Microelectronics	Develop micromachined structures & materials for miniature sensors & actuators Develop microacoustic sensors for target detection & CB sensing Develop miniature gyroscopes & accelerometers for inertial guidance	Develop miniature medical instruments for surgery Develop monolithically integrated miniature sensor/actuator microsystems Develop integrated sensor readout circuits for real-time information output	Develop embedded microsensors & actuators for automated missile guidance, structural failure prognosis, personal navigation, & medical diagnosis/treatment
Electronics Materials	Advance MOMBE & MOCVD single-wafer deposition technology Develop SiC process technology for high-temperature electronics & power devices Develop ferroelectric film for nonvolatile memory applications	Develop reliable sources of InP wafers Achieve heteroepitaxial growth of device-quality GaAs on Si Develop wide-bandgap SiC devices for high-temperature & high-power applications Develop ferroelectric nonvolatile memories for digital battlefield applications	Develop GaN materials & devices Develop accelerometers
Integrated Platform Electronics	Reduce tank crew manning 50% Demonstrate super-high-density connector on an SEM–E	Improve navigation technology by 1 order of magnitude in all environments Demonstrate tank crew 50% reduction using crewman's associate integration	Demonstrate immersion cooled SEM–E 1,000 W Demonstrate 20-GHz network for combined digital, video, & RF

O BATTLESPACE ENVIRONMENT

The Future Combat System and Objective Force will rely heavily on the technological advances made in understanding and managing the battlespace environment. This technology area involves the study, characterization, prediction, and modeling and simulation (M&S) of the terrestrial and lower atmosphere environments. The objective is to understand the impact of the environment on personnel platforms, sensors, and systems in order to enable the development of tactics and doctrine to exploit that understanding and to optimize the design of FCS.

The science of terrestrial and lower atmosphere environments emphasizes characterization and modeling of physical phenomena, processes, interactions, and effects associated with terrain and its surface and subsurface features, and its influences on the atmospheric boundary layer at scales important to land warfare. The focus is on (1) the generation, receipt, interpretation, characterization, dissemination, and M&S of terrain data and imagery; and (2) the characterization and forecast of the state of the atmosphere, the analysis and dissemination of those state parameters, and the determination of the impacts of the atmosphere. The new emphasis on high-technology weapons and short battles requires increased battlespace awareness products with greater spatial and temporal detail and increased demand for weather sensing prediction and analysis.

Commanders at all levels must know how the environment will impact their operations as well as the operations of their adversary and be able to use this knowledge for military advantage. Sensor and weapon system developers must also understand the effects of the environment on system performance to optimize design effectiveness. This investment will provide numerous improvements to future warfighting capabilities, including:

- An order-of-magnitude improvement in providing digital topographic data needed by the commander for optimized deployment, mobility, planning, and logistics support.
- High-resolution weather forecasts for incisive decisionmaking and enhanced operational capability in adverse weather, reduced weather-related damage, and reduced fuel costs.
- Models for predicting the state of terrain using high-resolution weather forecasts and terrain data to accurately assess the effects on sensors and mobility of dynamically changing environmental characteristics.
- Accurate representation of dynamic environment and terrain (DET) in simulations to permit more effective mission planning, rehearsal, and training.
- Realistic portrayal of the effects of the battlespace environments to reduce operational costs and reduce casualties.

Technology Subareas

The Army's Battlespace Environment applied research program is structured in two technology subareas: Terrestrial Environment (signature physics and fusion and topography), and Lower Atmosphere Environment (current battlespace weather, predicted battlespace weather, and decision aids).

The structure of this section follows the taxonomy specified in the "Battlespace Environment" chapter of the *Defense Technology Area Plan* prepared for OSD's DUSD(S&T).

BATTLESPACE ENVIRONMENT-RELATED STOs
Terrestrial Environment
3D Dynamic Multispectral Synthetic Scene Visualization
Advanced Geospatial Management for Information Integration and Dissemination
Rapid Mapping Technology
Lower Atmosphere Environment
Weather Impacts and Decision Aids for Mission Rehearsal, Training, and Battlefield Execution
Weather Effects and Battlescale Forecasts for Combat Simulation and Training
Profiler Data Fusion
Deep-Attack and Indirect-Fire Meteorological Improvement
Rapid Generation of a Common Synthetic Battlespace for Strike Force

1 Terrestrial Environment

The terrestrial environment subarea comprises signature physics and fusion and topographic research (Figure IV–20). Signature physics and fusion focuses on mitigating the adverse effects of snow, ice, and frozen ground on materiel and winter operations. Topographic research is focused on increasing knowledge of the terrain through improved generation, management, analysis, and modeling of geospatial data, including the exploitation of multisensor data. Objectives in terrestrial environment technology development include the following:

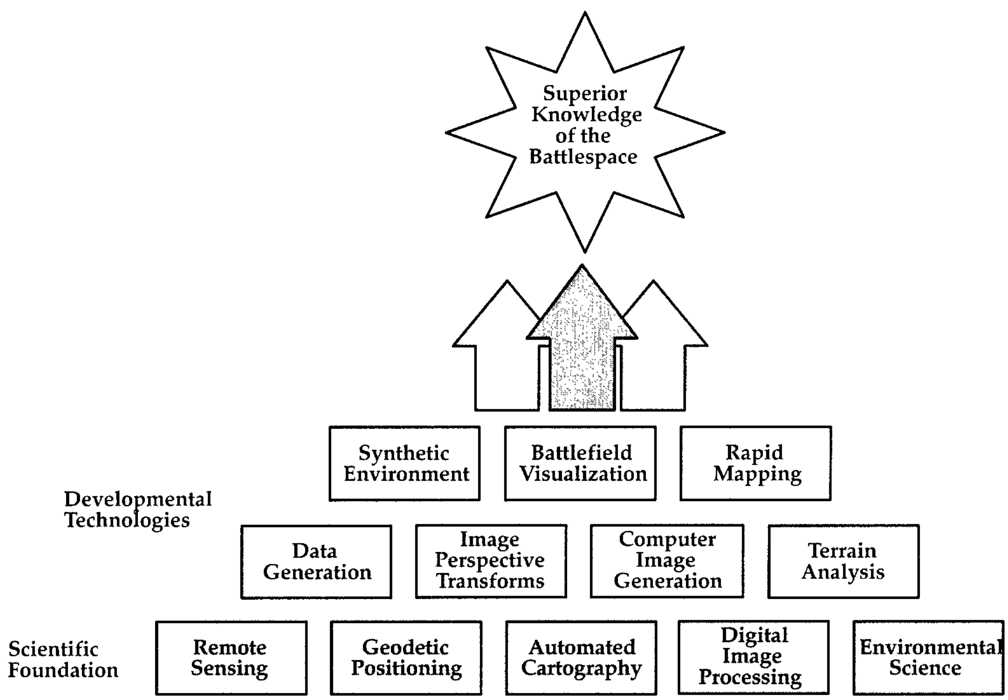


FIGURE IV–20. TOPOGRAPHY SCIENCE AND TECHNOLOGY

- Develop model-generated IR and MMW background scenes from terrain data and weather forecasts for a variety of terrestrial surfaces that show sensor performance and design (FY02).
- Demonstrate spatially distributed, physics-based, 3D ground state and weather effects in future distributed interactive simulations (DISs) (FY03).
- Develop multiscale/multiproduct geospatial data software capable of generating large integrated terrain databases (FY03).
- Develop and test 3D finite difference terrain model for seismic sensor detection, classification, and tracking algorithm refinement (FY04).
- Incorporate advanced detection, classification, and tracking algorithms and software into acoustic sensor testbeds (FY04).
- Demonstrate fusion of predicted IR and MMW sensor effects with terrain reasoning analysis for enhanced threat assessment and mission planning capability (FY05).
- Integrate thermal and IR/MMW sensor performance models with suitability and movement projection in C^2 systems (FY07).
- Develop battlespace flythrough/walkthrough and automated terrain analysis capability (FY07).
- Develop dynamic environment and terrain (DET) implementation for use with computer-generated forces (CGF) (FY07).
- Demonstrate knowledge-based systems for predicting the performance of multimode sensing systems (IR and MMW) over weather-impacted terrain (FY08).
- Demonstrate automated feature extraction and attribution capability (FY08).

a *Signature Physics and Fusion*

Signature physics and fusion focuses on minimizing or eliminating the dramatic effects of dynamically changing terrain state on sensing operations conducted by the Army. To do this, effective decisionmaking tools such as models, simulations, and mission planning and rehearsal factors are required that accurately predict the state of the ground, atmospheric conditions, and system performance in complex environments.

Goals

Complex environments present a formidable challenge to the performance and operability of weapon systems, targeting, reconnaissance and surveillance sensors, equipment, and dismounted warfighters. This challenge is not confined to the effects of weather. It also includes the various changes to the land surface affected by the weather. For example, frozen and thawing soils greatly affect the projection and mobility of forces, mine-clearing operations, and earth excavation required for force protection and construction. Changes in space and time of terrain characteristics and state properties significantly alter the propagation of acoustic, seismic, and IR energy as well as IR and MMW signature targets embedded in these complex backgrounds. This greatly reduces the effectiveness of weapon systems and sensors. Icing conditions reduce fixed- and rotary-wing aircraft performance; impact safe operation of equipment on roads, airfields, and bases; and impact the ability to communicate. Technical challenges in this area relate to developing and validating models of these phenomena and finding ways to exploit superior knowledge of these effects. The signature physics and fusion objectives are to:

- Develop first-principles models to predict the multispectral signatures of complex terrain surfaces and features for imaging sensor systems in all seasons. Models will be structured to provide simulation capabilities for evaluating environmental constraints early in the development cycle of developing tactics, training, and procedures for new and existing sensor systems, and to provide

accurate physics-based backgrounds for training simulations and tactical mission previews based on weather forecasts and on current and emerging terrain data.

- Develop techniques that allow seismic and acoustic sensor systems to maintain high-target resolution and characterization capabilities in complex terrain settings. This includes developing techniques to mitigate environmental effects on acoustic and seismic target tracking, range determination, and vehicle identification.
- Develop models of equipment and unit performance in winter conditions in sufficient detail to permit realistic M&S of these effects in combat simulations, analysis models, and operational planning tools.

Challenges

The challenges for terrestrial environment signature physics and fusion are:

- IR, MMW, and radar interactions with winter terrain surfaces (i.e., snow, ice, and frozen soil) vary significantly with changing meteorological conditions. The challenge is to model and predict the response.
- Acoustic energy propagation is distinctly different in winter than in summer. The technical challenge is understanding the coupling that occurs between the complex air, snow, frozen-ground, and unfrozen-soil interfaces.
- The impacts of low temperatures, snow, ice, frozen ground, and ice accumulation on the performance of materiel and equipment must be characterized to support design modifications, formulation of alternative techniques or procedures, and prediction of the extent and duration of the impacts.

b *Topography*

Knowledge of topography is essential to a common picture of the battlespace. Providing accurate and current information to the warfighter is the focus of topographic R&D. Topographic science is the delineation and representation of positions and elevations of natural and manmade features. S&T efforts are concentrated in the areas of standards, generation, analysis, representation, and management and dissemination.

Goals

Efforts are needed to provide technology for rapid generation of digital terrain feature and elevation data, data management, terrain visualization, terrain analysis and reasoning, and realistic mission training and rehearsal. The warfighter needs improved capabilities in all these areas to gain information dominance, shape the battlespace, and conduct decisive operations.

Developments focus on exploitation of imagery from multisource, multiresolution sensors, validation of geospatial data and algorithms, dynamic physics-based visualization and modeling, knowledge-based system surveying and positioning, and design of a smart digital map for the soldier. Tactics, techniques, and procedures are developed in parallel to enable the effective use of these new technologies in an operational context.

Objectives in topographic and geospatial information development include:

- Demonstration of advanced technologies in digital feature extraction and attribution, data management, the positioning of technologies beyond GPS, and the implementation of dynamic terrain into mission planning, rehearsal, and training systems.

- Use of knowledge-based techniques to improve terrain data exploitation for detecting and identifying geospatial changes and to predict terrain and climate effects over time in support of battlefield decisionmaking.
- Reduction of the time required to generate realistic environments in distributed M&S.

Challenges

The challenges for terrestrial environment topography are:

- Identifying terrain features and targets automatically to respond within the enemy's decision cycle.
- Developing a total force position and navigation capability for the Army. Accurate fire and the ability to locate and navigate will be key to success on the obscured future battlefield.
- Promulgating standard verified and validated software to achieve joint interoperability goals.
- Generating terrain and weather environments in near real time for tactical operations and distributed M&S.
- Developing a methodology to determine the effects of geospatial data and terrain-based models on battlefield decision aids, and displaying the results to a commander in order to minimize risk.

2 Lower Atmosphere Environment

The lower atmosphere environment is the near-surface region where Army personnel and systems function. Therefore, the requirement focuses on the atmospheric boundary layer—that portion of the atmosphere coupled to specific surface features. It is unique in its emphasis on the smallest spatial and temporal scales. Army efforts in these areas involve atmospheric measurements, data ingest and distribution, prediction and analysis of weather forecast/nowcast data, atmospheric propagation effects, weather for simulation, and development of tailored, system-specific weather decision aids. The following discussion breaks the Army contributions into three technology thrusts: current battlespace weather, predicted battlespace weather, and decision aids.

a *Current Battlespace Weather*

The current battlespace weather thrust is to provide the ability to determine current weather information and compute the corresponding atmospheric effects for a battle-size area anywhere in the world. This is accomplished through direct measurement and remote sensing of atmospheric parameters, and input of those data to the battlescale forecast model (BFM) to provide a near-real-time analysis of the battlespace atmosphere, including target areas. Under the Army Vision, this capability is particularly important to provide combat brigades and below with on-scene, ground-truth, and short-term nowcasts over typical domains of 60 × 60 km and supporting decision cycles of from 20 minutes to 2 hours.

Goals

Accurate and timely information on current weather and atmospheric information over critical parts of the battlespace is essential to situation awareness and immediate (3 hours) contingency planning. Combining the new capabilities of remote sensing systems operating from ground, air, and space platforms with covert, small-signature, in situ sensor platforms will result in new real-time data concerning the battlespace and target area meteorological environment. Such support—to brigade and lower echelons, down to individual platforms and soldiers—uses

"bottom-up," real-time data collection and assimilation. This differs greatly from the use of "top-down," longer range weather and effects forecasts at division and above.

Remotely sensed data with a forecast for a local 60- × 60-km area of interest increase the commander's confidence in planning and decisionmaking. Basic research focuses on the measurement and modeling of small-scale phenomena in the planetary boundary layer at resolutions often down to less than 100 meters, including aerosols, in addition to basic weather parameters (Figure IV–21). Where very high-resolution modeling is not feasible, assimilation of sensor and on-scene observations is essential. Methods are needed to use data taken at different times along a UAV or robotic vehicle path, fusing incomplete profile and point observations. Specific objectives include the following:

- Extract battlespace weather and atmospheric information from satellite remote sensors. Provide data from ground to space, covering 80 percent of the global surface, in under 4 hours, with up to twice the accuracy of current passive sensors (especially wind velocity gauges).
- Automate data retrieval from tactical weapon platform sensors. Increase battlespace data collections of meteorological observations and inferred environmental data by a factor of five over current sensors.
- Improve current objective analysis and numerical weather prediction models to fuse and assimilate nonconventional meteorological observations and derived environmental information taken at different times and at different points or paths throughout the forecast period. Produce a "cold-

Lower Atmosphere Environment: Current Battlespace Weather

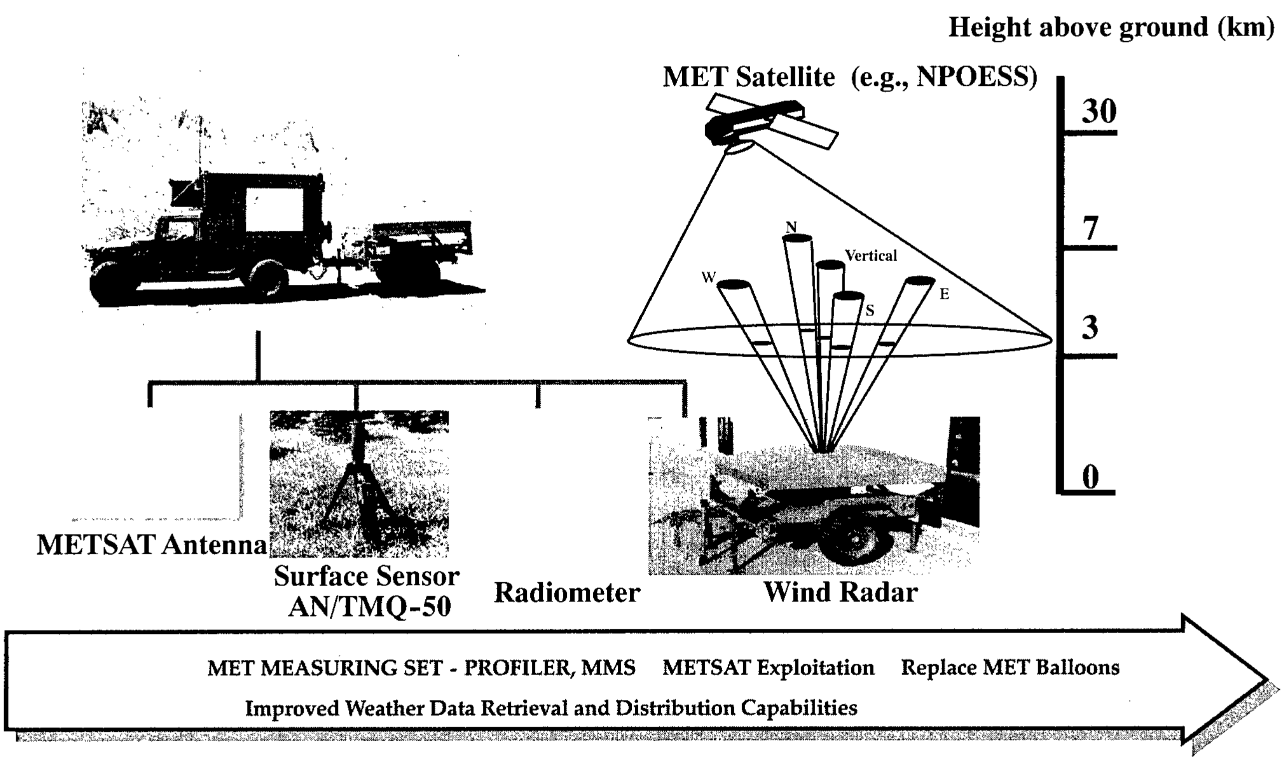


FIGURE IV–21. MEASUREMENTS IN THE PLANETARY BOUNDARY LAYER, ALONG WITH WEATHER PARAMETERS

start" objective nowcast and local forecast modeling capability that can be updated with new observations as needed.

- Identify and provide appropriate new weather products to support combat brigades, companies, and lower echelons with tools for data at 10 km down to tens of meters as short-term nowcasts and forecasts and for decision cycles of 20 minutes or less.

Challenges

The challenges for the lower atmosphere environment current battlespace weather are:

- Develop remote sensor concepts and algorithms to provide tactical data for initializing battlefield meteorological models, assessing performance of precision-strike weapons, and providing immediate real-time situational awareness on the battlefield.
- Develop distributed and networked measurement systems that resolve the microscale dynamic structures for the verification of atmospheric models operating at these scales. Technical barriers for basic research involve the investigation and explanation of previously unobservable atmospheric phenomena occurring at these scales, such as the convective boundary layer, gravity waves, and shear instabilities.
- Assess the accuracy of METSAT data extraction algorithms to determine which derived quantities are qualitative and which are sufficiently quantitative.
- Assess the actual value-added of ingesting measured on-scene meteorological data into nowcasts and forecasts. Modify existing numerical weather prediction models so that they can use conventional and unconventional data gathered from unconventional sensors and can assimilate new observations during model runs and from a "cold restart." Determine the optimum placement of deployable meteorological sensors in complex terrain.
- Determine the characteristics of aerosols, their dynamic properties in the atmospheric medium, and their optical properties over all spectral bands of military interest; and develop the instrumentation that permits the detection and analysis of aerosols. Determine both the qualitative and the quantitative accuracy of remote sensing extraction algorithms for METSAT and for sensors on other platforms.

b *Predicted Battlespace Weather*

The predicted battlespace weather thrust concentrates on methods to predict longer range atmospheric conditions on a high-resolution 3D grid over larger size battle areas anywhere and for any time from the present up to 120 hours in the future. Typical domains are 500 × 500 km for division and above planning and execution. These predictions use both reachback and on-scene numerical weather prediction meteorological modeling and analysis. Global- and regional-scale weather forecasts from Navy and Air Force weather central hubs are broadcast to the field. These forecast grids—together with on-scene surface observations, measured vertical profiles, data from aircraft such as UAVs, or remotely sensed airborne and METSAT data—are fused as boundary conditions and initializing data for additional meteorological model runs made at tactical operations centers. These models also factor in higher resolution local terrain information to provide more detailed 3D data grids that are not included in the other services' forecast data at near-surface levels where the Army is most impacted.

Large-scale, long-term Navy and Air Force numerical weather prediction models are routinely run at their centralized hubs and passed to the Army through commercial communication channels. This currently allows the Army to concentrate on refining these meso-scale forecasts from their 45- to 100-km horizontal data spacings and 3- to 12-hour time steps. The Army's models add local observations and more detailed terrain information to refine the forecast to smaller battlespace scales—currently between 4- and 10-km horizontal resolution, with more detailed

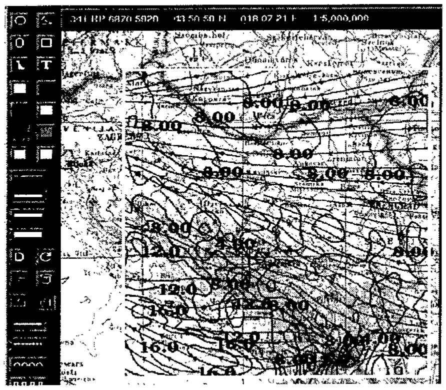
near-surface elevations down to 2 and 10 meters above ground level (AGL), and at output steps of typically 3 hours in time. The resulting gridded meteorological database is tailored to support the various Army C^2 systems, artillery meteorology, and detailed physics-based model for the effects of the atmosphere.

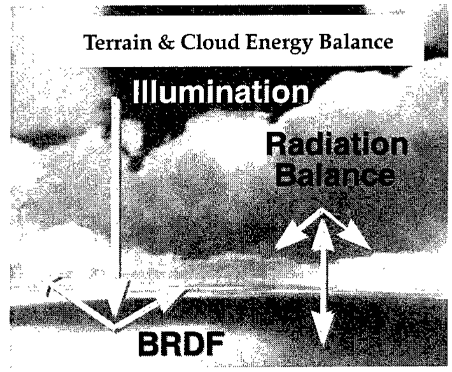
Goals

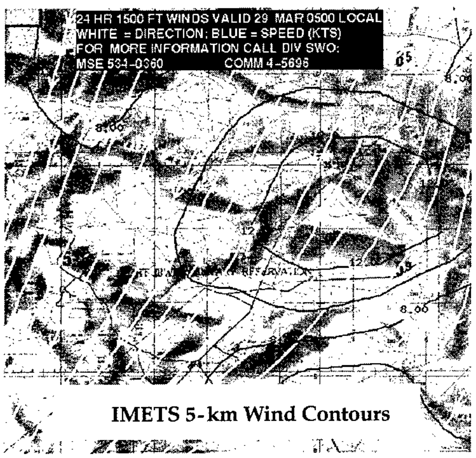
Advances in the regional and theater-scale models will allow reliable forecasts from the Navy and Air Force to extend from 72 hours to 120 hours at spatial resolutions down to 5 km. The Army will then be able to extend its battlescale forecast analysis tools to model weather features and effects at smaller spatial and time scales down to 100 meters and for mean-time averages down to 1 minute. (Random weather processes with fluctuations on the scales of minutes or less cannot be forecast; high-resolution dynamics and statistics of fluctuations can only be simulated at those scales.) Basic research thus focuses on modeling small-scale, mesoscale, and microscale meteorological processes, transport and diffusion, optical effects of the atmosphere on propagation through turbulence, and detailed physics-based models for effects of the atmosphere on EO and acoustic propagation and target acquisition. Diagnostic models are developed to account for terrain influences on wind transport and dispersion very near the surface. The physics in various new models from the numerical weather forecast community are compared and adapted to improve the physics of Army forecast models, such as in the areas of convective moisture and thunderstorm probabilities over land. Algorithms are developed for use across the services to process 3D grids of basic meteorological data into weather features and hazards, such as turbulence, icing, visibility, precipitation, and cloud cover (Figure IV–22).

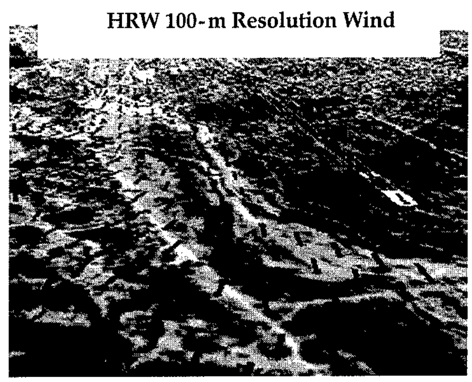
The objectives of the predicted battlespace weather technology thrust are as follows:

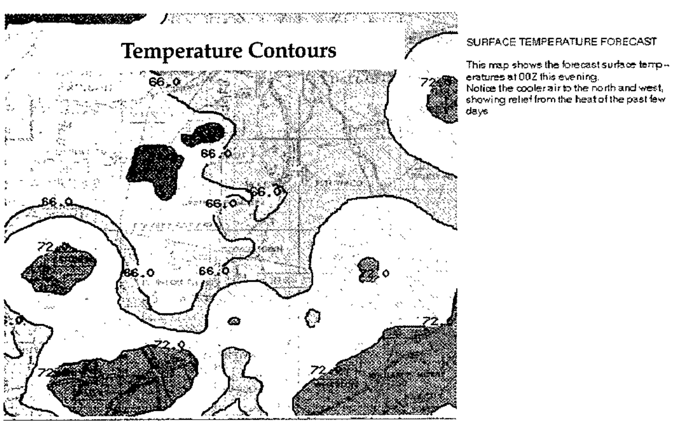
- Optimize environmental prediction models to allow them to operate on virtually all tactical weapon systems, from the future soldier to artillery and missile systems. Provide more accurate and timely data to support platform-independent decision aids.
- Develop an improved model for key weather elements and weather phenomena for important decisionmaking factors such as forecasts of turbulence, visibility, and icing, which can provide better nowcasting, forecast guidance products, and post-processed weather features and hazards to all services.
- Increase accuracy of indirect-fire cannon and missile systems by integrating the BFM directly into the ballistic kernel operating on fire direction center and gun platform fire control computers; and use the BFM to calculate, in near-real time, the meteorological effects over the entire trajectory path of a projectile, rather than just at the apogee.
- Integrate with the Air Force Weather Re-engineering program, which has centralized Air Force support for tactical Army weather. Incorporate the Air Force weather forecast model output into the Army tactical weather system to assimilate a wide range of data over complex inland and coastal terrain, account for improved cloud and aerosol treatment in the model physics, and improve surface energy balance and evapo-transpiration processes. Provide meteorological forecasts for elevations below 60 meters AGL.
- Develop descriptions of the dynamic flow interactions with highly complex terrain, vegetation, and structures that can run on a variety of computer systems, from battlefield workstations to supercomputers.
- Improve modeling for transport and diffusion (T&D) of gases, particulates, and pollutant plumes essential to DoD's CBW R&D programs. Couple T&D models to mesoscale numerical weather models to forecast aerosol dispersion and concentration.

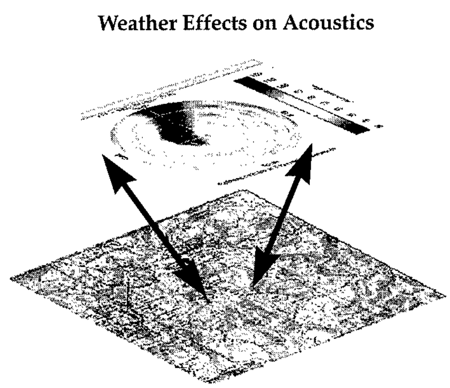












Finer Scale Forecasts 24 hr 48 hr Nonhydrostatic
CAAM*BFM/Artillery MET Artillery Fire Control Forecast
Illumination/EO Propagation T&D for CB Acoustics
IMETS Product Improvements and Battlefield Weather Visualization

FIGURE IV–22. LOWER ATMOSPHERIC ENVIRONMENT—PREDICTED BATTLESPACE WEATHER

- Link battlescale forecast models with gas and aerosol transport and diffusion models to provide 4D predictions of CB agent threats on the future battlefield. Increase accuracy of spatial forecast by 50 percent and concentration forecasts by 60 percent.
- Understand and model the propagation of acoustic and short-wavelength EM radiation in the atmosphere under natural and battle-induced conditions
- Develop high spatial and time-resolved effects of weather and illumination variations on EO propagation and target background signature models.

Challenges

The challenges for the lower atmosphere environment predicted battlespace weather are:

- Under Air Force Weather Re-engineering program, the Army receives gridded Navy and Air Force forecast weather data directly from an Air Force hub over Air Force commercial satellite communications links. The Army must be able to refine these data to provide a numerically stable forecasting tool that can be run for any time and location in the world. Since the ability to communicate local observations back to the central hub is limited, the Army forecast tool must be able to ingest local surface and upper air data.
- The current ability to accurately describe and predict very small-scale atmospheric mesoscale and microscale processes is very limited, especially for the boundary layer. For solution of problems at those scales, research is needed on new formulations of physical processes in the boundary layer at very short times and distances.
- The computational speed and memory/storage required to represent and predict mesoscale physical processes is extraordinary. The T&D of gases and particulates requires treatments more sophisticated than traditional Gaussian plume models to represent the turbulent, chaotic nature of atmospheric motions. Technical barriers for basic research involve the development of probability density function solutions in order to predict the concentration fluctuations—a critical issue for soldier system exposure; and the development of improved nonlinear solutions for the Navier–Stokes equations that describe the physical process of T&D.
- The flow of the atmosphere around and through vegetative canopies and through urban "canopies" plays a critical role in the use of countermeasures aerosols and for CBD. Models of such flow must be available for operation on tactical systems.

c *Decision Aids*

The decision aids thrust is to provide information in a simple and effective manner to decision-makers on the physical effects and performance impacts of weather on friendly and threat war-fighting capabilities. This involves comparing meteorological measurements and forecast data against validated critical weather value thresholds for each weather-sensitive system to produce tailored decision aids.

Decision cycles will shorten, and forces will be more dispersed and independent. Thus, future decision aids must operate on the tactical platforms, using all the data that the sensors and model provide, and produce the output in the most effective assimilation format. To be complete, the decision aids must include both threat and friendly systems, because the most important information is not system performance in isolation, but in comparison to the opposing force.

Goals

Weather impact decision aids will allow the commander to employ the weather as a combat multiplier (Figure IV–23). Specific objectives include the following:

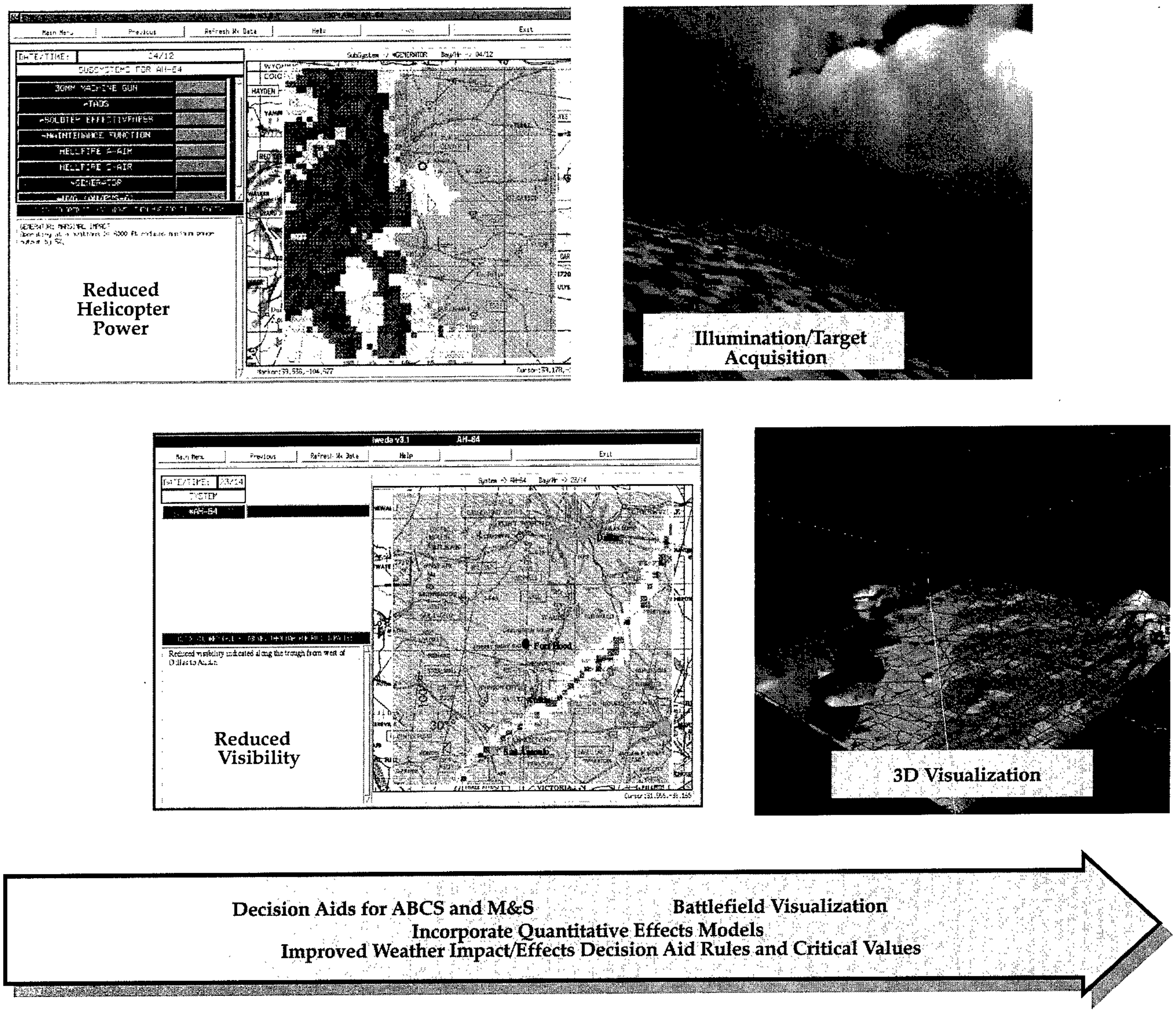


FIGURE IV–23. LOWER ATMOSPHERE ENVIRONMENT—WEATHER DECISION AIDS

- Develop integrated weather/atmospheric data, broad-spectrum propagation models, and advanced visualization methods to provide 3D visualized decision aids showing graphical depictions of atmospheric impacts on mission plans and weapon use for current and future battlefields.
- Automate mission planning tools, such as the Target Acquisition Weather Software, based on detailed knowledge of environmental impacts to optimize the commander's planning and decisionmaking ability. Improve the required mission output, as defined by the commander, by 30 percent over current methods.
- Integrate atmospheric and background models with target prediction models to ensure that atmospheric effects are included in the assessment of weapon system performance, survivability, and vulnerability.
- Develop environmental decision aids for operational and tactical levels of war planning and training that give the effects and impact of weather and battle-induced atmospheres on U.S., allied, and threat unit functions, systems, subsystems, sensors, and personnel.
- Develop real-time weather and environmental effects models (obscurants, illumination levels, EO effects, and acoustic propagation) to provide common, unified weather effects, features, and

representations leading to improved battlescale forecasting for simulation, training, doctrine, and C^3 systems that are compatible for all services.

Challenges

The challenges for lower atmosphere environment decision aids are:

- Rule-based weather impacts offer the most efficient way for faster-than-real-time aggregate war-games to play the impacts of weather. The simulation rule base must be consistent with the tactical decision aid rule base to promote both consistent C^4I and positive training.
- Battlespace prediction models and parameterization methods for boundary layer physical processes will depend to a great degree on in-theater data assimilation methods that fully exploit all sources of weather observations from remote and in situ platforms. Development of robust and flexible procedures will be needed to adapt to the available data options in real time.
- Development of comparable rule bases of weather impacts on threat systems are needed to balance the projected impacts on friendly systems. This capability must also show the "deltas" in performance impacts.
- The extension of weather impact decision aids from current rule-based, critical-value threshold comparisons to more complex interactions between weather, terrain, and performance characteristics will require greater use of AI, fuzzy logic, and expert system techniques that will require increased computational loads.
- Target acquisition models need access to current and forecast weather data to allow for proper selection of weapons and platforms.

Technology Objectives

The technology objectives for the Battlespace Environment are shown in Table IV–15.

TABLE IV–15. TECHNOLOGY OBJECTIVES FOR BATTLESPACE ENVIRONMENT

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Terrestrial Environments—Signature Physics & Fusion	Provide physics-based dynamic environmental effects on terrain models for inclusion into the synthetic battlefield Develop physics-based seismic target tracking & ranging capability for winter environments Develop rule-based approach for determining seismic & acoustic detection thresholds in winter & under windy conditions	Enhance physics-based 3D representation of complex terrain & weather conditions with modeling architectures that will allow practical application within DISNs Provide all-weather DET simulation for cold regions Provide physics-based models of acoustic & seismic signatures from heavy military vehicles; use models to overlay performance templates for terrain visualization, training, & tactical decision aids	Enhance performance of smart & brilliant weapons & surveillance systems development to distinguish target signatures within complex winter backgrounds
Terrestrial Environments—Topography	Incorporate techniques for processing SAR & ISAR feature data into existing software Incorporate & test initial spectral imagery automated feature extraction capability Improve visualization capabilities with the addition of dual-band IR & image intensifier capability Apply physics-based models to simulation applications Test link capability for point & line/vector geospatial data management Develop standards for the representation of & content of a link structure for geospatial data Develop ATN for combat support/close combat support vehicle usage Complete small-screen map display study	Incorporate automated feature extraction techniques from spectral, SAR, & EO sources into existing software Test initial automated feature attribution capability based on terrain reasoning software Extend physics-based models & visualization capability to incorporate passive & active MMW Integrate mode-derived IR & MMW sensor performance overlays into 3D visualization Test link capability for complex areal data management Deliver algorithms for management, dissemination, & integration of geospatial information to industry through the OpenGIS consortium Develop off-vehicle ATN Provide multiscale/multiproduct terrain visualization software	Investigate emerging satellite data for enhanced terrain feature generation & direct 3D imaging Investigate real-time automated feature attribution using multisource data Develop real-time dynamic atmospheric modeling Investigate & develop capability for fully automated real-time terrain visualization
Lower Atmosphere Environment—Current Battlespace Weather	Downsize prototype mobile Profiler for mounting on top of HMMWV shelter Demonstrate client/server architecture during division AWE Provide automated data retrieval from MMS to IMETS Provide automated data retrieval from IREMBASS MET sensor	Develop capability to determine wind speed & direction from satellite radiance data Provide seamless weather data distribution between services Develop capability to identify BW agents with portable biodetector	Replace meteorological balloons on battlefield with Profiler Automate data retrieval from tactical weapon platforms
Lower Atmosphere Environment—Predicted Battlespace Weather	Transition 24-hr BFM as server for weather effects clients on ABCS Develop CAAM time- & space-weighted model & BFM on MMS for increased artillery accuracy Demonstrate ability to determine wind flow over complex terrain & land use features such as vegetative canopies & built-up areas Incorporate illumination, target, & scene shadow effects into target acquisition model Demonstrate BFM & weather effects integrated into the common operating picture, seamlessly overlayed on terrain battlefield visualization products	Extend BFM to 48 hours, with higher resolution & increased accuracy Incorporate BFM in indirect-fire control computer to increase artillery accuracy Incorporate terrain & weather effects into operational CB hazards prediction model	Provide horizontal/seamless integration of automatic battlescale weather forecasting throughout ABCS Develop 3D acoustic propagation model for 20-km ranges
Lower Atmosphere Environment—Decision Aids	Integrate realistic weather from BFM & decision aids into environmental libraries for HLA simulations Integrate weather effects decision aids into ABCS	Provide IWEDA as tri-service software toolkit Develop decision aids that display 3D sound propagation over complex terrain Develop battlefield acoustic/seismic detection weather effects simulation	Meet weather requirements of advanced battlefield visualization systems & HLA simulations

P BIOTECHNOLOGY

The Army's biotechnology programs use the new tools of molecular biology and the principles of bioprocess engineering to exploit the genetic diversity of the biosphere. The foci of these programs are varied and include the development of biomimetic and biotic materials, construction of genetic libraries for the selection of recombinant proteins such as antibodies and bioactive peptides, genomic mapping and proteomic assays, and development of novel catalytic enzymes. Applications include ballistics protection and lightweight armor; chemical and biological agent detection, protection, and decontamination; environmental remediation and pollution prevention; and elucidating the molecular mechanisms of toxic industrial chemicals and materials. Biotechnologically derived products will have the advanced performance characteristics required of the medium and lightweight forces of the future Army. Medical prophylaxis and therapeutics and other medical applications are covered in the Biomedical section of this chapter.

Evolution has resulted in a biological diversity of unimaginable complexity, and recombinant technology coupled with bioinformatics now permits careful use of the biological world for military purposes. These efforts will be coordinated in full partnership with the private sector where the bulk of biotechnology investments resides. The National Research Council has established the Committee on Applications of Biotechnology to the Future Army to assess where commercially developed biotechnologies can be applied to military requirements, with specific emphasis on the future medium-weight force, and to make recommendations for orthogonal investments in areas of biotechnology with unique military applications. Further public oversight is provided by the Centers for Disease Control (CDC) and the Food and Drug Administration (FDA). The CDC tracks all shipments of controlled biological materials, and the FDA reviews biomanufacturing being performed to current Good Manufacturing Practices (cGMP) standards.

Technology Subareas

The Army's Biotechnology applied research program is structured in ten technology subareas: Molecular Recognition, Low-Observables Materials, Biosensors, Catalytic Enzymes, Molecular Toxicology, Bioprocess Engineering, Bio-Derived Electronic and Photonic Materials, Bio-Derived Nanoceramics, Biofouling and Biocorrosion, and Biopreservation of Food Rations.

1 Molecular Recognition

Biological molecules have a unique ability to detect materials with great specificity and sensitivity. Coupling these biological recognition molecules to assays and microsensors will enable the real-time detection of chemical and biological warfare agents.

Goals

There are three major parts of this subarea. First, monoclonal antibodies are being developed using both traditional hybridoma and more recent recombinant technologies. Highly specific antibodies are selected for their efficacies in a number of assay platforms, and their expression is scaled up in either hollow fiber bioreactors or large-scale fermentors (FY01–02). The second area is the design of oligonucleotide probes specific for pathogenic markers. The first two oligonucleotide-based assays have been delivered (FY00) with two or more per year to follow. The third area is peptide libraries. Initial libraries are being constructed (FY01) and will be screened for peptides with unique molecular recognition characteristics (FY02). These three areas are

supported by a cryorepository for validation and storage of all reagents. Longer term thrusts involve completely artificial molecular recognition sites (FY07).

Challenges

The major challenges for all these programs are to select molecular recognition sites of sufficient specificity and sensitivity to ensure that they function properly when stabilized and configured in assay format, and to scale up production in an economically advantageous bioprocess.

2 Low-Observables Materials

LO materials reduce the signature of a weapon platform, thus enhancing survivability in a hostile environment.

Goals

Current obscurant materials pose health and environmental risks and do not have a multispectral capability. The goal of this program is to develop biomaterials for use as smoke obscurants and low-observable coatings for the Future Combat Systems. The ideal materials will be multispectral, biodegradable, nontoxic, noncorrosive, and inexpensive to produce. Prototype organisms producing biomaterials with near-IR spectral characteristics have been identified (FY00), and the materials will be produced and subjected to chamber testing (FY01). Pending future funding, a larger library of organisms will be screened (FY01–02) for additional materials, which will be genetically manipulated to enhance their spectral characteristics (FY02). Candidate materials will be configured with conductive dendrimer polymers (FY03) and in polymer coatings (FY05) for field tests (FY06).

Challenges

Several challenges include enhancing the materials' absorption spectra into the millimeter-wave region, increasing yields in the production process, and configuring the biomaterials with polymeric materials to enhance both their obscurant properties and their potential application methods (i.e., aerosol dispersion or coatings).

3 Biosensors

Biosensors are devices that are used to detect CBW agents. Ideally, they should function in real time, with virtually no false positives or negatives.

Goals

Biosensors are amalgams of biological recognition elements (e.g., oligonucleotide probe) with a microsensor, the former providing the selectivity and the latter the signal transduction and amplification. Current-generation optical waveguides are ~0.03 percent optically efficient, requiring large amounts of power to boost the signal. A new generation of side-emitting optical biosensors with ~25 percent optical efficiency is being configured to detect toxic organic chemicals (FY02). This increased efficiency should reduced power requirements to microwatt levels.

Challenges

Key challenges are the modification of the existing detection chemistries to respond to the chemicals of interest, and multiplexing the sensor for multiple agents.

4 Catalytic Enzymes

Enzymes are proteins that catalyze reactions at ambient temperatures and pH. They can be used to degrade or destroy toxic chemicals with minimal deleterious effects to the environment or equipment.

Goals

Organophosphorus acid anhydrolases (OPAAs) and organophosphorus hydrolases (OPHs) have been selected, cloned, and tested for their ability to degrade chemical nerve agents. There are several goals for this effort. One is to increase the yields of these materials such that the biomanufacturing processing is economically feasible. Genes for green fluorescent protein have been fused with the gene directing the expression of OPH, the result being a process whereby OPH expression can be monitored directly in the bioreactor via fluorescence (FY01). Bioreactor conditions will be optimized to enhance the production of enzyme (FY02). Although OPH and OPAA have excellent activity against G-type nerve agents and many organophosphorus pesticides, they possess little or no activity against V-type agents. Both random and site-directed mutagenesis studies are underway to increase the substrate specificity range of these enzymes (FY01). These efforts will be expanded (FY02) to identify mutants with other favorable properties. In addition, incorporation of these and other enzymes into matrices of decontamination (firefighting foams and sprays, aircraft deicing solutions, laundry detergents, aqueous degreasers) and protection (cross-linked enzyme crystals, polyurethane foams cellulose and cotton fabrics) is an ongoing effort.

Challenges

OPH tends to form inclusion bodies in the cell, limiting recovery of product. The major challenge is to control bioreactor conditions such that this process is precluded. Identification of mutant or new enzymes with enhanced or novel properties against nerve agents requires screening against the actual agents. It is a significant challenge to screen potentially thousands of samples against the agents in a reasonable period of time. Incorporation of enzymes into such a broad variety of matrices requires significant stabilization of the enzymes.

5 Molecular Toxicology

Molecular toxicology looks at the toxic effects of hazardous materials at the cellular and genetic levels, identifying the mechanism of action of the materials.

Goals

Traditional toxicology studies using animals are ill suited to large-scale screening of toxic industrial chemicals (TICs) and toxic industrial materials (TIMs), especially in combination or at low levels. Cytotoxicity, genomic, and proteomic assays are being developed as in vitro approaches that can serve as a triage for animal studies as well as elucidate mechanisms of toxicity. Cytosensor microphysiometer studies of nerve agents, TICs, and TIMs using human cells have been completed (FY00), and genomic (FY01) and proteomic (FY02) assays are being developed. In addition, a corneal epithelial cell assay is in validation trials (FY01).

Challenges

Identification of specific genes and proteins, which are early indicators of toxic exposure, is the key challenge. Beyond that, obtaining FDA validation for a new in vitro assay represents a significant regulatory hurdle.

6 Bioprocess Engineering

Bioprocess engineering is a subdiscipline of biotechnology concerned with the manufacture of materials using biological systems.

Goals

Bioprocess engineering, also known as biomanufacturing, is the key to transitioning biotechnology research to the field. It involves designing the parameters for fermentation from small (5 liters) to large (1,500 liters) scale, extracting and purifying the biomaterial from the bulk cell mass, and developing methods for stabilizing and storing the product while retaining its functional properties. While there are similarities in process design for a given class (e.g., enzymes) of product, each process must be individually tailored for optimal economic efficiency. Ultimately, cGMP certification will be required.

Challenges

Scale-up to approximately 1,000 liters—the metric for a large-scale process—requires identification of all bioreactor parameters unique to the microbe and product being grown. A particular challenge is to identify the genetic response to stressors (e.g., feeding conditions, cell density) and to develop techniques to modify that genetic response to optimize production. A second major challenge is to ensure proper refolding of the protein product.

7 Bio-Derived Electronic and Photonic Materials

Bio-derived electronics and photonics are lightweight, flexible, rugged, and conformal films and coatings for electromagnetic shielding, antistatic coatings, and energy storage devices.

Goals

Biotechnological methods have been used to develop new, processable materials with desired electrical and optical responses for multifunctional soldier protection. Enzymatic polymerization will be used to synthesize a new class of soluble, conducting, and optically active polymers for such applications as lightweight power, biosensing, EMI shielding, stealthy materials, electrostatic dissipations, and corrosion protection. Current studies include characterization of these new polymers and development of methodologies that can effectively process and integrate these polymers into lightweight, useful, and durable coatings, composites, fibers, and textiles (FY01). These conducting polymers will be coupled to biological receptors such as DNA for the development of new, electrochemical biosensors (FY01). Genetic engineering of the enzymes will optimize catalytic function and scale-up (FY02–03). These polymers will be integrated in appropriate device architectures for soldier protection and sustainment capabilities (FY03–05).

Challenges

Reusability or genetic modification of the enzymes involved will be major challenges necessary to facilitate scale-up and commercialization of these technologies.

8 Bio-Derived Nanoceramics

Bio-derived nanoceramics are lightweight materials for improved ballistic protection.

Goals

Current mechanisms for forming ceramics involve harsh conditions and reagents. In nature, organisms can form ceramics under mild conditions using protein-directed templated crystallization mechanisms. The goal of this program is to develop a biologically driven method for producing nanoceramics. The first step was to genetically alter the active sites of ceramic templating proteins to favor ions such as boron and aluminum over calcium and silica crystallization seen in nature. Modified and unmodified versions of these proteins will be used to form novel ceramics in aqueous, semiaqueous, and nonaqueous environments (FY01). Methods for controlling the content and shape of the ceramic particles will then be developed (FY02–03). Eventually these nanoceramics will be produced in bulk for incorporation into composites for ballistic protection and other applications (FY07).

Challenges

Identifying the genetic modifications that will maintain the basic structure of the ceramic forming protein while encouraging binding to new ions represents one of the major technical challenges. Controlling the ceramic architecture by establishing synthesis conditions that will tailor the composition and morphology is also a significant technical hurdle.

9 Biofouling and Biocorrosion

Antimicrobial peptides retain activity after processing at high temperatures and in the presence of organic solvents. As a result of this stability, they are excellent candidates for polymeric coatings and films to extend the lifetime of fielded items.

Goals

Biocorrosion and biofouling represent major problems for fielded items. The goal of this program is to incorporate antimicrobial peptides into polymeric materials to prevent degradation. An array of naturally occurring antimicrobial peptides are currently being incorporated into polymeric cast films and electrospun membranes to demonstrate antimicrobial activity (FY00). Additional peptide and peptidomimetope candidates will be identified using a (bio)combinatorial synthesis approach to produce peptide libraries and screening for improved activity or stability (FY01). Surface attachment of effective peptides by covalent attachment is underway and will continue as candidate peptides are identified (FY01–02). Scaled up production of these peptides by biotechnological means (e.g., fermentation, transgenics) will be a key step to fielding items (FY02–03). Finally, incorporation into materials for field testing will be pursued (FY05).

Challenges

Interfacing polymeric materials with bioactive compounds and maintaining stability and activity are significant technical challenges. Furthermore, the identification of novel antimicrobial activity with (bio)combinatorial techniques and large-scale production are technical hurdles.

10 Biopreservation of Food Rations

Bacteriocins can be identified or developed to provide a class of unique molecules with antimicrobial activity and tailored specificity for food spoilage and pathogenic bacteria.

Goals

Military rations are often subjected to long periods of storage requiring rigorous preservation treatments that protect the food but reduce quality and taste. Bacteriocins—natural peptides produced by many food safe bacteria—inhibit the growth of food spoilage and pathogenic bacteria. Combining bacteriocins with standard preservation methods can extend the life of rations with limited changes in the quality and taste of the food. Current research is focused on cloning and expressing bacteriocin peptides. Using the bacteriocin peptides as a template, peptide libraries will be made and screened for enhanced activity and stability during food processing (FY01). These biopreservation elements will be tested in food products under various processing conditions (FY01–03). Scale-up production of bacteriocins having the desired properties will be conducted for end-product testing (FY04).

Challenges

The major challenges are to identify biopreservation elements that inhibit spoilage and pathogenic organisms; determine the appropriate concentration needed to be effective; determine the effectiveness of the biopreservation elements in a diverse heterogeneous environment such as a food ration; and gain regulatory approval to use bioengineer peptides in military foods.

Technology Objectives

The technology objectives for Biotechnology are shown in Table IV–16.

TABLE IV–16. TECHNOLOGY OBJECTIVES FOR BIOTECHNOLOGY

Technology Subarea	Near Term FY01–02	Mid Term FY03–08	Far Term FY09–16
Molecular Recognition	Genetically engineered antibodies	Oligonucleotide probes Peptide libraries	Synthetic reagents
Low-Observables Materials	Near-IR biomaterials testing	Testing biomaterials configured with conductive dendrimer polymers & in polymer coatings	
Biosensors	Configure new generation of side-emitting optical biosensors	CB detection	Distributed sensors with telemetry
Catalytic Enzymes	GFP/OPH clones Mutagenesis efforts Enzyme stabilization	Bioprocess for OPH production V-agent enzymes Formulation development	Enhanced activity and stability of enzymes
Molecular Toxicology	Microphysiometer assays	Proteomic arrays Genetic arrays	Validated in vitro assays
Bioprocess Engineering		CGMP certification	
Bio-Derived Electronic & Photonic Materials	Polymer processing of coatings & composites	Enzyme engineering	Multifunctional soldier protection
Bio-Derived Nanoceramics	Genetically engineered condensing proteins	Controlling architecture	Incorporation into composites
Biofouling & Biocorrosion	Antimicrobial films & membranes	Large-scale production	Field testing
Biopreservation of Food Rations	Bacteriocin clones Peptide expression	Bacteriocin libraries Testing in food	Large-scale production

CHAPTER

V

BASIC RESEARCH (DISCOVERY AND UNDERSTANDING)

CONTENTS

A ARMY BASIC RESEARCH PROGRAM V–3

B FUTURE OUTLOOK V–5

C INITIATIVES V–5

1 **Centers of Excellence** **V–5**
2 **DoD University Research Initiatives** **V–8**
3 **Historically Black Colleges and Universities and Minority Institutions** **V–12**
4 **Single-Investigator Programs** **V–13**
5 **Partnering With the Private Sector—The Federated Laboratory** **V–13**
6 **In-House Laboratory Independent Research** **V–16**
7 **Future Army Research Areas of Emphasis** **V–16**
8 **Army Strategic Research Objectives** **V–17**
a Biomimetics V–17
b Nanoscience V–18
c Smart Materials and Structures V–19
d Mobile Wireless Communications (Supports Information Technology SRA) V–21
e Intelligent Systems V–21
f Compact Power V–22
g Enhancing Soldier Performance V–24
h Microminiature Multifunctional Sensors V–25
i Armor Materials by Design V–26
9 **Other Academic Leveraging** **V–29**

D EXECUTION—SCIENTIFIC RESEARCH AREAS V–31

1 **Mathematical Sciences** **V–31**
a Strategy V–31
b Major Research Areas V–32
c Potential Military Benefits V–33
2 **Computer and Information Sciences** **V–33**
a Strategy V–33
b Major Research Areas V–34
c Potential Military Benefits V–35
3 **Physics** **V–35**
a Strategy V–35
b Major Research Areas V–35
c Potential Military Benefits V–36
4 **Chemistry** **V–37**
a Strategy V–37
b Major Research Areas V–37
c Potential Military Benefits V–39
5 **Materials Science** **V–39**
a Strategy V–39
b Major Research Areas V–39
c Potential Military Benefits V–41

6 **Electronics Research** **V–41**
  a Strategy V–41
  b Major Research Areas V–41
  c Potential Military Benefits V–42
7 **Mechanical Sciences** **V–43**
  a Strategy V–43
  b Major Research Areas V–43
  c Potential Military Benefits V–45
8 **Atmospheric Sciences** **V–45**
  a Strategy V–45
  b Major Research Areas V–45
  c Potential Military Benefits V–47
9 **Terrestrial Sciences** **V–48**
  a Strategy V–48
  b Major Research Areas V–48
  c Potential Military Benefits V–50
10 **Biomedical Research** **V–50**
  a Strategy V–50
  b Major Research Areas V–51
  c Potential Military Benefits V–52
11 **Biological Sciences** **V–53**
  a Strategy V–53
  b Major Research Areas V–53
  c Potential Military Benefits V–55
12 **Behavioral, Cognitive, and Neural Sciences** **V–55**
  a Strategy V–55
  b Major Research Areas V–56
  c Potential Military Benefits V–57

E SUMMARY **V–57**

LIST OF FIGURES

V–1	Laureates Who Have Contributed to Army Programs	V–4
V–2	Burgeoning Applications of Biomimetics for the Objective Force	V–18
V–3	Nanometer-Scale Micrograph	V–19
V–4	Smart Composite Actuator Concept and Army Applications	V–20
V–5	Mobile Wireless Communications	V–22
V–6	Intelligent Systems	V–23
V–7	Compact Power Sources	V–23
V–8	Enhancing Soldier Performance	V–24
V–9	Microminiature Multifunctional Sensors	V–26
V–10	Armor Materials by Design	V–27
V–11	Numerical Simulation of Impact and Large Deformation	V–32
V–12	Software and Knowledge-Based Systems	V–34
V–13	Atom-Beam Fiber Coupler	V–36
V–14	Synthesis of Designed Molecules/Dendrimers	V–38
V–15	Material Synthesis	V–40
V–16	Advancements in Device Integration and Information Capacity Through Solid-State and Optical Electronics Research	V–42
V–17	Passive/Active Damping Control for Rotorcraft Systems	V–44
V–18	Sensing Atmospheric Properties	V–47
V–19	Terrain Features	V–49
V–20	Payoffs From Biomedical Basic Research	V–52
V–21	Biological Sciences Research Strengthens Objective Force Opportunities	V–54
V–22	Salivary Amylase Field Assay Kit	V–58

LIST OF TABLES

V–1	Basic Research Responsibilities of Department of Army Components	V–2
V–2	An Example of the Composition of an Executive Advisory Board and Technical Advisory Council for a Center of Excellence (Center for Intelligent Resin Transfer Molding for Integral Armor Applications)	V–6
V–3	Army Centers of Excellence	V–6
V–4	Army Multidisciplinary University Research Initiative Centers	V–9
V–5	ARL Federated Laboratory Participants	V–15
V–6	Basic Research Goals Associated With Strategic Research Objectives	V–28
V–7	Impact of Basic Research Areas on Army mission Areas	V–59
V–8	The Dynamic Nature of Basic Research Programs	V–60
V–9	Recent Awards Received by Scientists and Engineers for Research Sponsored by the U.S. Army	V–61

CHAPTER

V BASIC RESEARCH (DISCOVERY AND UNDERSTANDING)

Without strong basic research, the foundations for the development of future technologies will not be laid.

—STAR21 Study
National Research Council

The Army invests in basic research to provide the force with technological superiority. Fundamental research is the "seed corn" for technological discoveries and advancements. The Army's basic research:

- Fosters progress and innovations in Army-unique areas (e.g., armor and antiarmor) or in areas where commercial incentive to invest is lacking due to limited markets (e.g., military medicine to develop vaccines for tropical diseases).
- Shapes research and technological innovations concerning issues related to Army applications and environments.

In this way, the Army can develop or adapt its technology needs for the ever-increasing variety of missions it faces. The Army's dependence on technology is increasing as it evolves toward smaller, lighter, more lethal forces. The investment made in basic research today will shape the future Army by providing the technological building blocks needed to address imperatives emerging from future warfighting concepts.

Senior Army management is committed to a sustained basic research program that supports the Army's needs. To this end, the Army structures a coherent basic research program and integrates extramural research that leverages the power of academia and industry with in-house research in critical, Army-unique areas. The resulting science base provides the foundation for follow-on applied research (6.2) and, eventually, advanced technology development (6.3) programs.

The Army research program is managed by Army laboratories and centers. Within the Army Materiel Command (AMC), the Army Research Laboratory (ARL) supports several centers of excellence, manages the federated laboratories, conducts in-house research and, through its Army Research Office (ARO), manages extramural programs through the university single-investigator program, selected Centers of Excellence (COEs), and University Research Initiative (URI) programs. Finally, the research, development, and engineering centers (RDECs) conduct research through the in-house laboratory independent research (ILIR) program. The Army Medical Research and Materiel Command, the Army Corps of Engineers, and the Army Research Institute for Behavioral and Social Sciences also conduct a mixture of intramural and extramural research programs, as shown in Table V–1.

TABLE V–1. BASIC RESEARCH RESPONSIBILITIES OF DEPARTMENT OF ARMY COMPONENTS

Basic Research Mission	Emphasis of Research	Execution Strategy
	ARMY MATERIEL COMMAND	
Conduct & sponsor basic research unique to the Army & in areas assigned to AMC by DoD in support of other agencies. AMC basic research spans a wide range of disciplines that not only increase the soldiers' battlefield standard of living, but also serve as the foundation for increased knowledge, speed, & lethality in the theater of operations Ensure that research supports future operational capabilities Make technology work for soldiers	Lethality Energy efficiency Lighter, smaller components Protection & survivability Specific areas are: • Missiles • Vehicles (tracked & wheeled) • Guns & artillery • Aviation • NBC • Nutrition & food sciences • Textiles • Testing • Sensors, electronics, communications • Simulation & training devices • Armor (personnel, vehicle, weapon systems) • Multispectral camouflage • Mobility • Ammunition	Partnership with TRADOC to focus on future warfighting doctrine & required capabilities Ensure that basic research is conducted as an integral part of the Army's S&T investment strategy to realize the Objective Force vision Leverage industry, national laboratories, & academia Consortia with national organizations Participate in international organizations ARL executes Army intramural research in-house & through federated labs & COEs ARL/ARO has the focus on basic research, executing extramural research through URIs, COEs, & individual investigators Move basic research successes from ARL to wherever they can be applied: to AMC RDECs; to industry; or directly to the soldier
	ARMY MEDICAL RESEARCH & MATERIEL COMMAND	
Exploit basic science to define potential biomedical solutions to overcome military-unique threats to health & combat health care delivery constraints, & maximize the operational performance of the warfighter	Infectious diseases of military importance Combat casualty care Military operational medicine Medical chemical & biological defense	Perform studies & exploit civilian basic biomedical research to define injury mechanisms of military health threats Maintain in-house expertise, including uniformed medical scientists to avoid technological surprises & maximize ability to meet military needs Selectively invest in critical extramural capabilities Leverage industry & other government agency programs, exploiting unique Army capabilities to facilitate discovery of dual-use technologies Maximize efficiency through tri-service coordination via the Armed Services Biomedical Research Evaluation & Management Committee
	ARMY CORPS OF ENGINEERS	
Conduct basic research in various disciplines, including civil engineering & environmental sciences, to expand knowledge base & allow applied research for future operational capabilities in the following areas: • Mapping, terrain analysis, & image processing • Environmental quality • Combat & support operations in cold regions or cold weather • Airfields & pavements for strategic & operational capabilities • Mobility models supporting virtual prototyping to operation use • Construction, operations, maintenance, & repair of installations • Atmosphere–terrain interactions	Signature analysis (radar & spectral analysis for data generation) Terrain analysis & reasoning Energy propagation in terrestrial environments Pavements & airfields Smart materials Hardened construction materials Multispectral materials for field fortification/structural camouflage & concealment Vehicle–terrain interaction Hazardous/toxic waste management & remediation Hazardous wastewater management Biogeochemical processes Quantifying impacts of military operations on natural & cultural resources Groundwater & runoff modeling Snow/ice/frozen ground properties & processes	Identify & execute research efforts focused on the Army vision & FOCs & capabilities Establish & maintain liaison support to primary customers Develop strategy to support internal teaming & external partnering Transition basic research successes in a timely manner
	ARMY RESEARCH INSTITUTE FOR BEHAVIORAL & SOCIAL SCIENCES	
Conduct scientific research that underlies & supports the development of people-related technologies in: • Training—improve the retention of skills & the transfer of skills to field environments • Personnel—improve recruitment, retention, & the Army's ability to address social issues • Leadership—improve the assessment & development of skills	Training research Personnel research Leadership research	Aim research to future-oriented issues Coordinate research with applied scientists to increase chance of transitions Call upon world-class scientists for conduct of research

Without the scientific base developed by these activities, the Army would not have in its arsenal many technologies that are now taken for granted and that have been used effectively in recent military operations around the world. The ultimate payoff of basic research is the translation of concepts into technological applications.

APPLICATIONS EVOLVED FROM BASIC RESEARCH
The concept of inverted populations of excited quantum states translated into a laser
Use of fast mathematical procedures to calculate Fourier transforms for fire support
Advanced materials from basic principles to yield required properties and performance
Incorporation of small, superfast electronic devices into systems
Precise atomic measurements transitioned to GPSs
Nonlinear mathematical techniques that are the basis for secure Army communications
Mathematical simulation techniques yielding application-specific microprocessors for Army use

The Army is increasing its dependence on technology to increase its lethality and survivability, decrease its logistics burden, maximize its situational awareness, lighten the force, and enhance soldier performance. To become technologically superior, there is a continuous and essential emphasis on basic research in enabling breakthrough capabilities, exploiting technological opportunities, taking advantage of surprise technological discoveries, and interpreting and tailoring progress for the Army's benefit.

A ARMY BASIC RESEARCH PROGRAM

The Army's basic research program is a critical and integral part of DoD's *Basic Research Plan* (BRP). The DoD BRP encompasses 10 scientific disciplines and formulates broad visions of what might be achieved in each of them. It also presents six strategic research areas (SRAs) that define rapidly expanding research fronts with the potential for high military benefit.

The Army's basic research program is closely tied to the DoD-recognized scientific disciplines and the six DoD SRAs through its corresponding Strategic Research Objectives (SROs). In addition to the six DoD areas, the Army pursues three additional SROs. These Army programs and roles are detailed in the following sections of this chapter.

The program is managed and executed to focus knowledge in areas critical to the Army. It initiates and fosters revolutionary research that is capable of providing innovative new opportunities for the future Army, and evolutionary research that is responsive to identified needs. The level of investment is dependent on:

- Emerging technological opportunities.
- Future Army concepts and perceived needs.
- The ability to leverage investment for many applications and from other services/agencies.
- Commercial investments.
- Program continuity.
- Viable support for selected areas (e.g., DoD SRAs, Army SROs).

EXTRAMURAL RESEARCH INVESTMENT (60% of Funds)
Give leverage to the power of academia and industry
Focus world-class research on Army challenges
Allow for flexibility to capture new discoveries
Complement the intramural efforts

INTRAMURAL RESEARCH INVESTMENT (40% of Funds)
Help maintain "smart buyer" capability essential to the Army
Give leverage to government-unique facilities
Support Army-unique niche efforts
Support world-class researchers in areas critical to the Army

An approach to Army basic research is based on three complementary driving forces:

- Exploitation of basic research opportunities and discoveries (revolutionary innovations).
- Pursuit of SRAs/SROs, particularly those related to the DoD *Joint Vision 2010* and Army Objective Force concepts.
- Maintenance of land warfare technical subdisciplines (evolutionary research).

The Army's basic research program has a track record of significant contributions. From the world's first electronic digital computer (ENIAC) to enhancements to the Patriot missile system and the continuing innovations of military medicine, the program has made a measurable difference. The extramural program has leveraged world-class researchers across the spectrum of technical areas, including Nobel Prize winners and innovators in areas such as lasers, superconductors, electronics, and displays (Figure V–1). The recent Nobel Prize for fullerenes was in fact awarded to scientists whose research was supported by the Army Research Office.

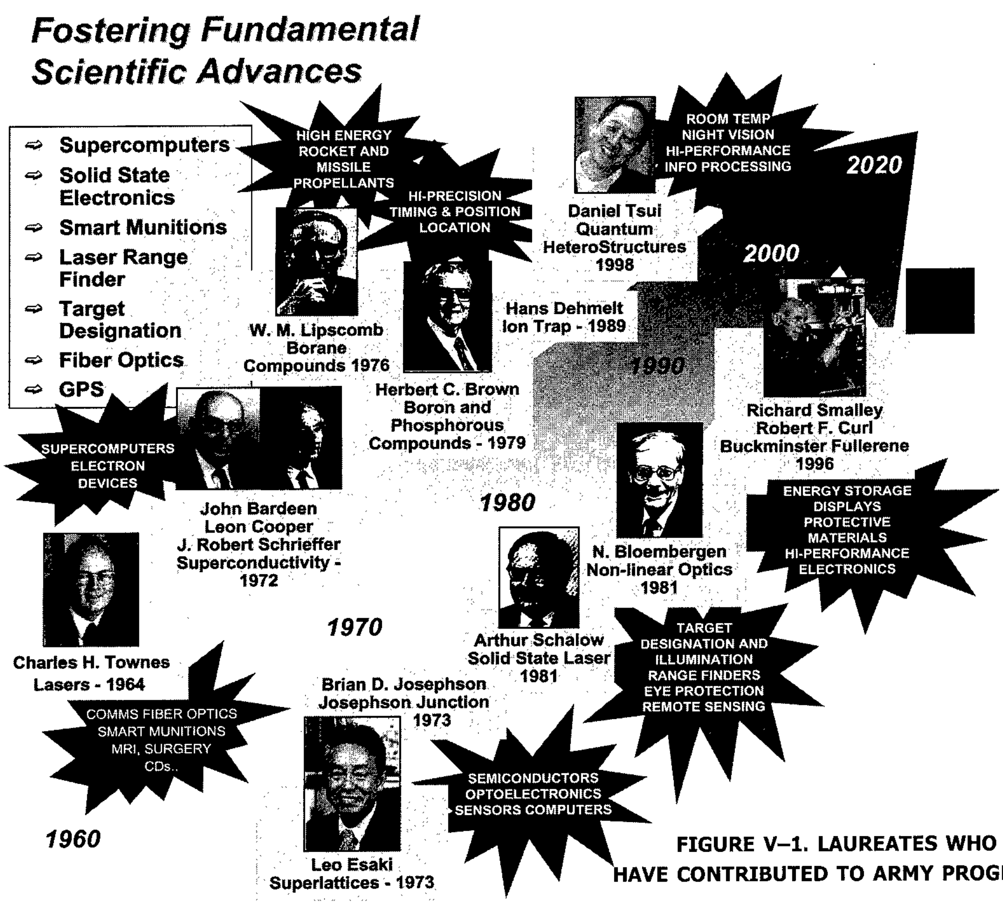


FIGURE V–1. LAUREATES WHO HAVE CONTRIBUTED TO ARMY PROGRAMS

Today, the Army has a significant number of capabilities that are direct results of our prior investment in basic research. These capabilities include the special armor on the M1 tank, advanced penetrators, antimalaria drugs, and hepatitis A vaccine. The current basic research investments are critical to the emergence of capabilities for the Objective Force, including lightweight ballistic protection, mobile wireless communications, robotics, high-density compact power, smart structures for rotorcraft, and ubiquitous training systems.

B FUTURE OUTLOOK

The primary challenges facing the Army today and into the future are to make its heavy forces more strategically deployable and more agile with a smaller logistical footprint, and its light forces more lethal, survivable, and tactically mobile than today's forces. In planning its basic research program, the Army uses the Objective Force construct to provide focus to the overall program. A key role for the Army basic research program is to foster innovation and understanding in the sciences. The Objective Force will benefit from all 6.1 basic research because the discoveries of today are the enablers of tomorrow's technologies and upgrades to Future Combat Systems.

The intramural basic research carried out within the Army's laboratories and research centers, and the extramural basic research sponsored at more than 300 academic institutions, will provide the essential science to enable the Objective Force. The information contained in the Strategic Research Objectives and Scientific Research Areas sections of this chapter outlines the planned basic research to enable the Army to meet the technology challenges establishing the Objective Force.

Although true "breakthroughs" in science are not predictable, a few key areas offer the potential for leap-ahead opportunities in future warfighting capability. Advances in molecular biology, for example, will facilitate the design and discovery of vaccines and prophylactic drugs to prevent illness, new vaccine delivery systems, rapid diagnostic tests, receptor-targeted immunization against BW agents, and catalytic scavengers against a broad range of CW agents. Biomimetics and biomimetic processing research may lead to new electro-optical materials, chemical detectors, and structural, multifunctional smart materials. Advances in the new field of quantum computing will revolutionize cryptography with the ability to manipulate massive databases in the areas of wargaming, logistics, battle management, and C^3. Research in nanotechnology will produce ultra-high-density memory devices and higher speed electronic processing capabilities as well as intelligent, hybrid, and multispectral sensors and new structures, armor, and chemical barrier materials.

The broad search for new technologies for the Objective Force is continuous. Basic research is the "insurance" against the unknown. The goal is to prevent technological surprise.

C INITIATIVES

The Army's basic research program takes advantage of numerous Army and DoD initiatives. These initiatives not only help to support and orient funding for specific research areas, such as COEs, university research centers, and historically black colleges and universities (HBCUs) and minority institutions (MIs), but also provide guidance for future Army needs such as the SROs and Objective Force. Those initiatives having the greatest impact on research programs are described in this section.

1 Centers of Excellence

COEs continue to be an integral part of the Army's research investment strategy, along with single-investigator programs and Army laboratory research. Centers have proved to be effective in many application-oriented projects in areas such as rotary-wing technology and electronics.

Interdisciplinary research requires the joint efforts of many scientists and engineers and also often requires the use of expensive research instrumentation that is difficult for a single investigator to acquire. Center programs often couple state-of-the-art research programs with broad-based graduate education programs to increase the supply of scientists and engineers in areas of Army importance. Historically, the Army has led DoD in the concept of such research centers with critical mass funding.

The scientific research undertaken at each COE and URI center (see next section) is dynamic and undergoes continuous review based on criteria provided for assessing the quality of the programs. These criteria include reviews by executive advisory boards that represent high-level management of industrial and military organizations and by technical advisory councils that represent technical personnel from multiservice organizations. Table V–2 illustrates the composition of a typical management and technical panel—in this case the Center for Intelligent Resin Transfer Molding for Integral Armor Applications.

TABLE V–2. AN EXAMPLE OF THE COMPOSITION OF AN EXECUTIVE ADVISORY BOARD AND TECHNICAL ADVISORY COUNCIL FOR A CENTER OF EXCELLENCE (CENTER FOR INTELLIGENT RESIN TRANSFER MOLDING FOR INTEGRAL ARMOR APPLICATIONS)

Executive Advisory Board	Technical Advisory Council
Chairperson, Director, ARL Weapons & Materials Directorate ARL/ARO, Director, Materials Science Division National Aeronautics & Space Administration, Langley, Director, Vehicle Structures Directorate Aviation and Missile Command, Technical Director Tank–automotive & Armaments Command, Technical Director Soldier and Biological Chemical Command, Chief of Staff	Chairperson, ARL/ARO, Materials Science Division ARL, ST, Weapons & Materials Directorate ARL, Scientist, Weapons & Materials Directorate University of Delaware, Scientist, Composites Manufacturing Science Laboratory Edgewood Research, Development, & Engineering Center, Scientist Tank–automotive Research, Development, & Engineering Center, Chief, Manufacturing Technology Branch McDonnell Douglas Missile Systems, Senior Group Manager—Composites Lockheed–Martin, Manager, Advanced Programs United Defense Ground Systems, Manager Composite Structures

Army COEs are active in the research areas summarized in Table V–3. This table identifies each COE research area together with the participating universities, summarizes the scope of each program, and highlights future plans. Some of these centers have had significant collaborative participation by HBCUs and MIs, a trend that the Army will be encouraging for future COEs. In addition, industry is encouraged to increase their participation in Army COEs to leverage and synergize the investment in these collaborative efforts. Table V–3 notes COEs funded directly by the Army and also those managed by the Army but funded by DoD.

TABLE V–3. ARMY CENTERS OF EXCELLENCE

Research Areas/ Participating Universities	Scope	Future Plans
	ARMY FUNDED	
Scientific Foundations of Image Analysis Johns Hopkins University	Mathematical & algorithmic foundations of image science Fundamental performance limits on ATR systems Detection & recognition bounds	Multisensor fusion & information theory Image compression & ATR systems Representations for cluttered backgrounds
Science, Engineering, & Mathematics (SEM) Education Contra Costa College*	Coordinated program to increase number of underrepresented graduates in SEM Prescribed, sequential coursework Internships & summer programs Outreach programs	Enrolling 250 students over a 5-year period in science/ mathematics programs Providing solid foundation in science & mathematics Facilitating transfer to institutions awarding higher degrees Encouraging careers in SEM

TABLE V–3. ARMY CENTERS OF EXCELLENCE (CONT'D)

Research Areas/ Participating Universities	Scope	Future Plans
	ARMY FUNDED (CONT'D)	
Automotive University of Michigan	Advanced ground vehicle modeling & simulation Vehicle dynamics & structures Advanced & hybrid propulsion systems Man–machine interface Simulation-based optimization	Military vehicle technology assessment Cost/performance tradeoff study Benefits of intelligent transportation systems technology
Microelectronics University of Maryland	Nanoelectronics & optoelectronics CB detection Wide-bandgap electronics Integrated terahertz devices	Uncooled infrared sensors Optical interconnects Individual biodetectors High-speed signal processing
Johns Hopkins University	Piezoelectronics & electrochemistry Microelectromechanics High-resolution display technology	Microsensors New battery concepts New fuel cell concepts
University of Virginia	Integrated terahertz devices Quasi-optical electronics	High-speed signal processing MMW electronics
Howard University*	Wide-bandgap electronics	High-temperature/high-power electronics Electromagnetic environment protection devices
Materials Johns Hopkins University	Advanced materials characterization Nondestructive material evaluation Surface/interface characterization Ceramic glasses, armor ceramics MMCs Nanophase & barrier materials	Joining of advanced materials Nonintrusive process monitoring Nanomaterials characterization Functionally gradient materials Transparent armor materials Testing microspecimens
University of Delaware	Composite materials research Integral composite armor Processing science Microstructure & bonding Mechanics & durability	Graded density composites Multifunctional armor Low-cycle fatigue behavior Impact damage mitigation Fiber interphase engineering
Michigan Molecular Institute	Dendritic polymer materials Polymer synthesis/modification Physical property characterization Metellodendrimers	Chemical decon Biotoxin detection Fiber surface coatings Dendritic nanocomposites
High-Performance Computing Research University of Minnesota	Computational fluid dynamics Fluid-structure interactions Base remediation & environmental protection	Adaptive & mesh moving gridding techniques Multidisciplinary (aerostructural) modeling Computational environment development Advanced algorithms for large-scale applications
Clark Atlanta University*	Fluid-structure interactions	Adaptive & mesh-moving gridding techniques Multidisciplinary (aerostructural) modeling
Florida A&M University*	Base remediation & environmental protection	Advanced algorithms for large-scale applications
Howard University*	Computational fluid dynamics	Computational environment development
Jackson State University*	Base remediation & environmental protection Computational chemistry	Advanced algorithms for large-scale applications
Northwestern University	Structural mechanics	Advanced algorithms for large-scale applications
Rotorcraft Georgia Institute of Technology	Efficient solution for aeroelasticity Affordability Wake lifting surface interaction Residual strength & fatigue life Helicopter limit detection & avoidance Integrated flight controls	Slotted & circulation control rotors Aeroelastic & stability analysis; carefree flight control Finite element analysis of composite rotors Strength & life of damaged composites Wake-lifting surface interaction; dynamic inflow Robust & adaptive flight controls

TABLE V–3. ARMY CENTERS OF EXCELLENCE (CONT'D)

Research Areas/ Participating Universities	Scope	Future Plans
ARMY FUNDED (CONT'D)		
University of Maryland	Low-vibration dynamic systems Smart & composite structures Day/night adverse weather Digital-optical integration flight controls Efficient low-noise rotors Advanced drive trains	Elastomeric dampers & bearings Vibration reduction & stability augmentation Computational fluid dynamics Low-noise fuselage panels for cabins Near-wake definition, aeroacoustics Reconfigurable flight control systems
Pennsylvania State University	Aeromechanical analysis with dampers Active/passive hybrid systems Interior noise reduction Vibration control systems Health monitoring system	Active control of internal noise reduction Active/passive control of damping Health monitoring of helicopter rotor systems Wireless rotor control, sensing, & anti-icing Optimal design of an active rotor & airframe vibration
Biotechnology New Mexico State University*	Web site for biotechnology information Workshops/symposia in bioinformatics Database annotation & curation Generation of novel databases	Single-point Web access for genomic & functional databases Course modules for K–12, post-secondary education Database curation services
Information Sciences Clark Atlanta University*	Interactive/intelligent systems & database Parallel/distributed systems & communications Cognitive engineering & display systems Human resource development Interaction/technology exchanges	Collaborative planning/decisionmaking for Army warfighters Information assurance & dominance Tactical Internet/intranet technologies for command & control Software engineering & database technologies
Hypervelocity Physics & Electromechanics Research Institute for Advanced Technology, University of Texas at Austin	Fundamental understanding of launch, flight, impact & lethality Rail/armature & launch effect electrodynamics Fundamentals of pulse power for electric armaments Supporting educational & assessment activities	Validating superior performance of HV projectiles Armatures & rail materials for robust, efficient launchers Support to pulsed alternator development, alternative pulse power approaches
Modeling & Simulation Institute for Creative Technologies University of Southern California	Immersion technology Networked simulation Computer-generated characters Algorithms & techniques for generating synthetic natural environments	Entertainment industry technology in creating synthetic experiences Visual prototyping of equipment and concepts Mission planning & rehearsal Adaptable leader training
DOD FUNDED		
Advanced Distributed Simulation Grambling State University Consortium*	Parallel & distributed computing Heterogeneous multimedia database Interactive graphics & visualization	Advanced distributed simulation Student training & education program Enhanced research infrastructure Man–machine interface
Intelligent Resin Transfer Molding for Integral Armor Applications Tuskegee University* Consortium	Intelligent resin transfer molding (RTM) for integral armor applications RTM process/manufacturing, sensing & control Process modeling/phenolic resins Bonding, repair, & ballistic performance	Smart weave & sensors in RTM Virtual manufacturing of RTM process Materials & process issues for integral armor Performance modeling, simulations, & testing
Science, Engineering & Mathematics Education Morehouse College*	Unification of multiple departments to enhance programs & increase underrepresented graduates in SEM Summer study, field trips Mentoring/research programs Scholarship & outreach programs	Enhancing quality of science & mathematics instruction in secondary schools Increasing majors in SEM Increasing number of graduate students in SEM Encouraging careers in SEM

*Historically Black Colleges and Universities or Minority Institutions.

2 DoD University Research Initiatives

The Office of the Secretary of Defense continues to support a portfolio of programs characterized as URIs. All DoD services share the funds for this portfolio, nominating and investing in subject areas and activities best correlated with their research and technology needs.

A series of 5-year block grant URI programs, most funded at about $400,000 per year, concluded in FY96. More than 30 university groups performed research for the Army on topics in biology, advanced propulsion, materials, high-frequency microelectronics, electro-optics, nanotechnology, energy, manufacturing science, environmental sciences, and intelligent control systems.

During each year since FY94, several new 5-year multidisciplinary university research initiatives (MURIs) have been started, most funded at about $1 million per year. The MURIs typically engage two or more science/engineering departments within a university (sometimes with other academic or industrial partners). Achievements not attainable through work in a single specialty are sought. For example, new levels of intelligence in control of rotor blades requires the collaborative expertise of investigators in mathematics and computer science as well as in the fields of aerodynamics and aerostructures. For another example, successful experiments with extremely small turbine engines require the collaborative expertise of investigators in propulsion as well as in manufacturing science, and perhaps other fields. Table V–4 lists the Army MURI centers, the scope of their research programs, and future plans.

The URI program also supports the National Defense Science and Engineering Graduate Fellowship Program. Other URI activities supported in FY98 and FY99 included the Defense Experimental Program To Stimulate Competitive Research, the Infrastructure Support Program for HBCUs and MIs, the Defense University Research Instrumentation Program, the Focused Research Initiative, and a Young Investigator Program.

In addition to the technical programs and resulting accomplishments of the URI and COE efforts, another major output from these Army-funded academic programs is the support and graduation of technical students—many of whom go on to work in Army laboratories or allied industries.

TABLE V–4. ARMY MULTIDISCIPLINARY UNIVERSITY RESEARCH INITIATIVE CENTERS

Research Areas/ Participating Universities	Scope	Future Plans
	TERMINATING IN FY01	
Active Control of Rotorcraft Vibration University of Maryland	Exterior (rotor) noise & vibration control Interior noise control Transmission noise & vibration control	Mach-scaled rotor tests Comprehensive acoustic & vibration analysis techniques Innovative noise & vibration control concepts
Damage-Tolerant Lightweight Armor Materials Purdue University University of Dayton Research Institute University of California, San Diego	Novel materials & structures design concepts Processing, fabrication, & testing of materials Advanced analytical methods	Layered, oriented, & gradient materials systems Dynamic viscoplasticity models for anisotropic materials Solution of inverse problems
Low-Energy Electronics for Mobile Platforms University of Michigan	Top-down design methodology Optimization of all system design levels Software implementation	Minimum-energy information exchange Integrated platform system design Adaptive & minimum-energy processing High-performance devices & components
Photonic Band Engineering University of California, Los Angeles	Improved microwave/MMW devices Efficient microlasers & smart pixels Low observables & identification friend or foe	Photonic crystals for electromagnetics Demonstration of low-threshold lasing Nonlinear image processing
Integrated Approach to Intelligent Systems University of California, Berkeley	Design of hierarchical control architectures for multiagent systems Perceptual systems Framework for representing/reasoning with uncertainty Soft computing approaches to intelligence augmentation	Intelligence augmentation for human-centered systems Fully autonomous systems Battle management

TABLE V–4. ARMY MULTIDISCIPLINARY UNIVERSITY RESEARCH INITIATIVE CENTERS (CONT'D)

Research Areas/ Participating Universities	Scope	Future Plans
	TERMINATING IN FY01 (CONT'D)	
Demining Duke University University of Missouri, Rolla Northeastern University	Mine, ordnance, & explosive detection, identification, & location Sensor & information fusion Neutralization	Mine detection & location under realistic weather & environmental conditions Enhancement of P_d Minimization of false-alarm rate
Rapid, Affordable Generation of Terrain & Detailed Urban Feature Data Purdue University	Advanced photogrammetric & image understanding research Image understanding research for terrain analysis	Mathematical modeling for multisensor registration Automated extraction of remote sensing cues Automated feature recognition Unsupervised classification for hyperspectral imagery
Predictive Capabilities Based on Performance Metrics for Automatic Target Recognition for Military Applications Brown University	Quantitative understanding of ATR capabilities & limitations Metrics for structured clutter Metrics for scene complexity	Analytical frameworks for classifying images Algorithm-independent bounds on ATR performance Metrics to predict & measure the performance of ATR implementation
Biomimetics & Biomimetic Processing University of California, Santa Barbara	Biomimetic processing Mineralization in organic substrates Control of hierarchical structures	New EO devices Chemical detectors Structural materials New multifunctional & smart materials
	TERMINATING IN FY02	
Clustered Engineered Materials Northwestern University	Laser ablation/molecular beam cluster growth Nanosphere liftoff nanopatterning Self-assembled nanoclusters	Biological agent detection Photocatalysis for decontamination Efficient frequency conversion
Quasi-Optic Power Combining Clemson University California Institute of Technology	Spatial & quasi-optical power combining Hybrid power combining Array phase control Device/electromagnetic field interaction	Economical sources & arrays of MMW power Reduced size, weight, & phase noise Enhanced reliability & durability Enhanced array functionality beam steering, modulation/ demodulation, & nonlinear function Reciprocal arrays, transmit & receive through common aperture
Design & Control of Smart Structures Harvard University With Boston University & University of Maryland	Modeling & experiments with MEMS for flow control over airfoils Mathematical framework for modeling & controlling fluid motion Parallel array microvalves for flow control	Ferrofluidic micropumps for drug delivery MEMS devices for flat-panel displays Controlled deformable mirrors & antennas
Dendritic Polymers University of Illinois	Property discovery using combinatorial libraries Computational modeling to guide synthesis & properties Surface engineering & adhesion studies Synthesis & scale-up of polymeric materials	Responsive protective coatings & sensor coatings Catalysts for chemical agent destruction Volatile-organic-compound-free coatings Super-tough, processable elastomers Lubricants for solids & liquids
	TERMINATING IN FY03	
Defect Engineered Nanostructures Princeton University	Investigating fundamental issues Microscopically characterizing structures Elucidating influence of defects on performance	Integrating & mass producing quantum-based devices Reducing size & power consumption
Olfactory Sensing California Institute of Technology With Harvard University & Yale University	Characterizing olfactory receptor & pathway function Computational neurobiology & modeling of sensory mechanisms Molecular recognition	Insight regarding olfactory processes Enabling biomimetic approach Engineered olfactory system analogs
Adaptive Optoelectronic Eye University of Southern California University of Michigan	Man-made sensors that adapt & interact similar to animal vision Smart & adaptive emulation of biological eye Determining functionality of biological vision	Machine vision for sensing systems for navigation, surveillance, target recognition, & real-time machine interactions with humans Merge microelectronics, micro-optic, & micromechanical devices Scheme for detecting, processing, & transmitting near-perfect optical images

TABLE V–4. ARMY MULTIDISCIPLINARY UNIVERSITY RESEARCH INITIATIVE CENTERS (CONT'D)

Research Areas/ Participating Universities	Scope	Future Plans
TERMINATING IN FY03 (CONT'D)		
Microthermal Engines Massachusetts Institute of Technology Georgia Institute of Technology	Understanding & producing millimeter-sized devices to reengineer traditional heat engines at mesoscale level Investigating new refractory ceramic micromachining Developing new bonding & micromolding	Power generation or cooling Replacing batteries for individual soldier High-speed rotary micropower generation
Digital Communication Devices Based on Nonlinear Dynamics & Chaos University of California, San Diego	Generating digital signals by an integral nonlinear element, not a circuit or an integrated circuit Investigating simple microelectronic devices for control	Implementing mobile wireless communications Securing digital transmissions with small, lightweight, low-power equipment Securing communications for the battlefield Spinning off to information theory
TERMINATING IN FY04		
Hybrid Molecular & Spin-Semiconductor-Based Research Purdue University	Understanding fundamental issues for hybrids combining organic molecules & semiconductors Multidisciplinary program for quantum devices for switching & memory, low-light-level photodetectors & biomolecular optoelectronic devices leading toward novel computing paradigms	Hybrid organic & inorganic optoelectronic devices at the nanometer scale Sensor applications at low light levels, chemical & biological with preprocessing built in
High Selectivity in Biological Detection University of Texas	Enabling generation & use of biomolecular or biomimetic recognition & signaling elements for biological functional groups Providing enabling scientific knowledge & technical capabilities for molecular manufacturing of sensor systems for biological detection	Real-time detection of biological functional groups New capabilities in biological defense, counterterrorism, & verification of nonproliferation
Tunable Optical Polymeric Systems University of Rochester	High-quality basic study in chemistry, materials science, physics, & supporting disciplines to focus on molecular assembly, design, synthesis, & optical properties of materials such as electrochromic polymers & liquid crystal polymers Demonstrating wavelength-tunable light emission & controlled reflectivity from conformal films & materials	New technologies in flexible helmet & windshield displays, tunable-color wallpaper, & massive outdoor displays
Biomimetic Materials With Adaptive Infrared Response Rice University University of California, Los Angeles	Novel solutions for material surfaces that exhibit selective response to the IR electromagnetic spectrum Synthesizing, theoretically modeling, & characterizing biomimetic material & new structures	Providing emissive & modification equivalent to IR response of a chameleon-like effect Reducing or enhancing military vehicle signatures
Science Base for Nanolithography University of New Mexico	Comprehensive, multidisciplinary research program to address fundamental issues in achieving sub-100-mm lithography Determining the practical limits of lithography	Fabricating communications & information devices & systems with greatly expanded functionality, ultra-low-power operation, & miniaturization Allowing new functionalities & capabilities based on nanometer phenomenology
TERMINATING IN FY05		
Data Fusion in Large Arrays of Microsensors (SensorWeb) Massachusetts Institute of Technology	Developing a quantitative basis for information processing in large arrays of distributed microsensors Determining self-calibration requirements & algorithms Determining fundamental limitations on data fusion in multi-modality distributed sensing Creating suites of events to test data fusion algorithms for closeness to optimality	Advanced data fusion for increasingly intelligent, dynamic, & precise identification of military threats; for battlefield weather/condition prediction; & as substitutes for landmines Monitoring military or terrorist activity in urban areas or under heavy foliage Using data fusion in the civilian economy for security, environmental monitoring, manufacturing networks, & intelligent traffic systems
Mobile Augmented Battlespace Visualization University of California, Berkeley	Determining fundamental algorithmic principles for mobile computation, visualization, augmented reality, representation of uncertainty or confidence, & human display & interaction	Mobile computing combined with novel augmented reality display & interaction methods for improved situational awareness for the mobile warfighter & commander

TABLE V–4. ARMY MULTIDISCIPLINARY UNIVERSITY RESEARCH INITIATIVE CENTERS (CONT'D)

Research Areas/ Participating Universities	Scope	Future Plans
TERMINATING IN FY05 (CONT'D)		
Solitonic Information Processing University of Central Florida	Coordinated experimental & theoretical research program to gain deeper understanding of the physics of spatio-temporal solitonic systems Exploring new mathematical structures that embody "computability" with solitons & new materials that embody requisite properties	Solitonic smart reprogrammable/reconfigurable interconnects that help couple device components, eliminating crosstalk, enhancing intermediate highly parallel computing/signal processing, & incorporating neural nets in the coupling of optoelectronic components Greatly increasing information flux throughput
Quantum Computing & Quantum Memory California Institute of Technology Massachusetts Institute of Technology University of California, Los Angeles Additional support from Defense Advanced Research Projects Agency	Exploiting new capabilities, wrought by quantum mechanics & nanotechnology that can never be achieved classically Demonstrating a functioning quantum communications system, based on quantum teleportation, complete with quantum error correction & quantum memory Transmitting information in a secure manner over 100 km	Breaking existing cryptographic code Optimizing limited resources for wargaming, logistics, & resource routing Revolutionizing means of transmitting sensitive or vital information in military or commercial settings using unbreakable keys & quantum mechanical nonlocality
Ultra-cold Atom Physics Yale University University of Colorado, Boulder	Developing advanced sources of ultra-cold atoms Refining techniques for manipulation, characterization, & control of the atoms Developing theoretical understanding of & experimental capability to exploit the coherent wave nature of the atoms	Developing novel sensors, atom lasers, nanofabrication techniques, & precision measurement techniques Using ultra-cool atom optics to direct-write subnanometer-resolution device fabrication & new electronic devices that utilize novel quantum effects

3 Historically Black Colleges and Universities and Minority Institutions

Special programs for HBCUs and MIs have been important to the Army for many years. In 1980, the ARO initiated one of the first programs designed to involve HBCUs and MIs in Army research activities. Over the years, the ARO HBCU and MI single-investigator research program has grown to several million dollars annually. Since the early 1990s, there have been other initiatives to enhance participation of HBCUs and MIs in R&D programs of the Army laboratories and RDECs. Goals common to all of these programs include (1) strengthening the science, mathematics, and engineering curricula at HBCUs and MIs, (2) enhancing their ability to participate in defense research activities, and (3) increasing the number of underrepresented minority graduates in science, mathematics, and engineering. The AMC is dedicated to increasing the participation of HBCUs and MIs in all of its programs, particularly in R&D activities.

In addition to the programs mentioned above, the ARL/ARO manages the DoD Infrastructure Support Program for HBCUs and MIs, which provides approximately $14 million annually to HBCUs and MIs through grants made by ARL/ARO, the Office of Naval Research, and the Air Force Office of Scientific Research. Since 1992, the DoD program has awarded $111 million to HBCUs and MIs, including $42 million in ARO grants. These include programs such as collaborative research, instrumentation for research and education, COEs, and education centers for science, engineering, and mathematics. Two of the HBCU/MI COEs supported by ARL/ARO grants are consortia comprising several HBCU or MI partners, ARL partners, and industry partners. Their research focuses on advanced distributed simulation and intelligent resin transfer molding for integral armor applications.

Other HBCU/MI COEs supported by ARL/ARO funds include a center for SEM Education at Contra Costa College and the National Biotechnology Information Facility at New Mexico State University (see Table V–3).

Single-investigator research programs remain a significant part of the ARL/ARO HBCU/MI program and involve every discipline represented in the ARL/ARO interest spectrum. In FY99, the ARL/ARO's core program supported over 30 single investigators and totaled $2.2 million. In FY99, ARO's HBCU/MI involvement from all funding sources included the award of more than 60 grants totaling $16 million. (See Chapter VI for additional information on support of HBCUs/MIs.)

4 Single-Investigator Programs

A major contributor to the Army science base is the single investigator working at a university and, to a lesser extent, in industry. These Army-sponsored researchers act as windows into the academic world for exploration of scientific discoveries. Individual investigators provide the Army with the ability to broadly influence the total science base, quickly exploiting opportunities that might arise. The research areas included in the single-investigator programs are relevant to Army needs and subject to scientific peer review. History has shown that the single-investigator program has contributed significantly to the Army science base, with 10 Nobel prizes awarded for Army-sponsored research. The areas of research pursued by the single investigator are discussed in Section D.

5 Partnering With the Private Sector—The Federated Laboratory

The Army Research Laboratory is the second oldest reinvention laboratory in the Army. It was also the only research laboratory to be designated as a pilot project under the Government Performance and Results Act of 1993. These two designations have enabled ARL to be a reinvention leader in the DoD R&D community.

The single most significant reinvention undertaken is a revolutionary change to the core business process—performing fundamental and applied research. That reinvention—the Federated Laboratory (FedLab)—was enabled by the delegation of authority to ARL to utilize cooperative agreements as a vehicle to partner with the private sector. These partnerships spring from the need to perform research in which the Army has a compelling interest, but in which the private sector has the resources and assets already invested. Cooperative agreements allow the Army to work intimately with private sector partners rather than at arm's length as contractual arrangements require, thus continuing the development of the Army's in-house technical competence while strongly leveraging the private sector's. Over the past 4 years, this collaboration has effectively transformed ARL into a geographically distributed, virtual laboratory fully one-third larger than it actually is.

The AMC has a key research initiative to support the Army's thrust to digitize the battlefield. The objective of the Army digitization effort is to ensure the superiority of command and control systems by providing the warfighter with a horizontally and vertically integrated digital information network. This network will provide a simultaneous, consistent picture of the battlefield from soldier to commander at each echelon, as well as across all services and allied forces. ARL has prime responsibility for the AMC's intramural research program. Because of the vast private sector investment and expertise in these technology areas, ARL has successfully applied the FedLab partnering methodology to the digitization technology problem. This approach has produced an effective synergy between government, industry, and academia that will provide the maximum return on Army resources by:

- Adopting an integrated approach that combines the best of the public and private sectors to achieve future land warfare capabilities.
- Creating complementary government–industry–academia technology consortia that codevelop research plans annually to ensure that they are focused on Army needs. Reviews are conducted quarterly by the government to ensure that technical relevance is maintained and that consortia are executing their plans as scheduled. The laboratory also conducts program reviews with DDR&E reliance panels and the Army RDECs.
- Conducting an annual technical symposium during which the results of the past year's FedLab work are presented and displayed. At the four annual symposia held thus far, the attendance has averaged over 800, among which were cooperating researchers, RDECs, battle laboratories, and program manager customers. Oral presentations, poster sessions, and live demonstrations showed a breadth of remarkable technical accomplishments. These symposia also demonstrate the degree to which the results emerging from the three consortia are being integrated toward the single goal of digitizing the battlefield.
- Achieving research collaboration between traditionally disparate communities by balancing the mix of government, industry, and academic participation. This program has nearly 450 private sector participants, which amounts to a 5-to-1 leveraging of intellectual talent by the 90 ARL researchers involved in the three consortia.
- Promoting cross-pollination of ideas among consortia members spread throughout the country, an exchange fostered by long-term staff rotations between ARL laboratories and consortium members. To date, 22 university and 12 industry participants have rotated to ARL, and 17 ARL employees have rotated to various consortia member sites.
- Employing a unique management concept in which the government and partners, through consortium management committees, collaboratively develop and adjust research plans as formalized in each consortium's *Articles of Collaboration.*
- Integrating the ARL research program with those at other Army and DoD components to ensure that there will be a smooth transition of research results and that there is no duplication of effort.
- Providing a way to adapt commercial technologies to the unique needs of the military environment, and allowing government research to impact the industry protocols and standards of the future.

In January 1996, the Army awarded three cooperative agreements, each with several technical areas deemed critical to the overall digitization problem: telecommunications and information distribution, advanced and interactive displays, and advanced sensors. The partners in the three consortia are shown in Table V–5.

TELECOMMUNICATIONS AND INFORMATION DISTRIBUTION
Wireless communications
Tactical/strategic interoperability
Information distribution
Multimedia concepts
ADVANCED AND INTERACTIVE DISPLAYS
Soldier-centered computer interface
Perception (sensory)-based display formats
Cognitive measures of C^2 performance
ADVANCED SENSORS
Multidomain smart sensors
Multisensor fusion
Radar
Signal processing
Microsensors

Since FedLab has always been treated as an extension of ARL's in-house research program rather than a separate effort, its success will continue to be determined through the use of the ARL Performance Evaluation Construct. This construct was developed as part of a pilot project under the Government Performance and Results Act (GPRA). It consists of a multidimensional approach to performance evaluation by looking at quality, relevance, and productivity for all customers and stakeholders. It makes use

TABLE V–5. ARL FEDERATED LABORATORY PARTICIPANTS

Telecommunications/Information Distribution	Advanced & Interactive Displays	Advanced Sensors
	INDUSTRY LEAD	
Sanders, a Lockheed–Martin Company	Rockwell-Collins International	Sanders, a Lockheed–Martin Company
	HBCU/MI PARTNERS	
Howard University Morgan State University City College of New York	North Carolina A&T	Clark Atlanta University University of New Mexico
	ACADEMIC & INDUSTRY PARTNERS	
Bell Communications Research GTE Laboratories Massachusetts Institute of Technology Motorola University of Delaware University of Maryland	Microelectronics Center of North Carolina Sytronics, Inc. University of Illinois	Environmental Research Institute of Michigan Georgia Institute of Technology Research Institute Lockheed Missiles and Space Company Massachusetts Institute of Technology Ohio State University Research Foundation Stanford University University of Maryland University of Michigan Texas Instruments

of peer review, customer and stakeholder feedback, and metrics. The program will also continue to be part of the overall ARL business planning process. This process was also a result of Army GPRA activities. Both the planning process and the evaluation construct have gained a wide reputation both in the government and in the private sector as having broken new ground in research management.

Over the first 4 years of the partnerships, 28 technology products have transitioned out of the three consortia to ARL customers. In July 1998, the Vice President's Hammer Award was presented to the Army Research Laboratory. This award, given by the Vice President's National Partnership for Reinventing (NPR) Government, recognized 11 ARL team members for their contributions to the conception, creation, and implementation of FedLab. Of the more than 1,000 Hammer Awards presented by the NPR, this was one of the very few (if not the only one) awarded for an R&D initiative.

Entering the fifth and final year of the current consortia cooperative agreements, ARL is preparing to initiate a competition for the next generation of partnerships. FedLab has been so successful in all its aspects, and has been recognized as such by the extensive praise it has received, that the intent is to recompete the three existing consortia and expand the concept to three new consortia. The expanded construct will be called the Collaborative Alliances in Technology. These new alliances will be in the areas of advanced sensors, advanced decision architectures, communications and networks, robotics, power and energy, and information assurances. As in the original concept, these new alliances will consist of partners representing the very best research organizations from industry and academia with special expertise in these technologies that are critical to the future Army. An important change will be the inclusion of other government agencies, and especially our customers—the RDECs—as full partners in these alliances. This approach will serve to enhance and accelerate the transitioning of the results of the alliances' research products into system development programs.

In addition to establishing these alliances, other substantive improvements in the original FedLab structure and management processes will be based on lessons learned from the successes of the past 4 years. At the recommendation of the National Research Council, the cooperative agreements will be for 8 years rather than 5, thus providing more time to harvest the results of

the research program. ARL will concentrate on transitioning technologies to its principal customers, the RDECs. Aside from the inclusion of customers and other government agencies in the alliances, a 6.2 contractual component will be added to this formerly 6.1-only program, thereby allowing ARL to fund opportunities for transitioning the alliances' products on a continuing basis.

6 In-House Laboratory Independent Research

In-house laboratory independent research is a traditional part of the Army's basic research program. ILIR allocates 6.1 discretionary funds to the directors of selected Army research organizations to fund in-house research projects of exceptional scientific quality that have high risk but also very high potential payoff to the Army's S&T programs. ILIR funds are distributed to Army RDECs, the Corps of Engineers, the Medical Research and Materiel Command laboratories, and the Army Research Institute (ARI). ILIR is reviewed yearly by the Office of the Assistant Secretary of the Army (Acquisition, Logistics, and Technology) (OASA(ALT)) using metrics developed to assess programmatic effectiveness. The yearly review examines the quality, relevance, productivity, and resources of the ILIR work performed by each organization and determines its ratio of ILIR funding for the next fiscal year. This review results in only the best performers being rewarded. Within each organization, innovative research proposals submitted by scientists and engineers compete for ILIR funding through internal management and technical reviews of the proposals.

Upon their completion, successful ILIR projects will typically lead to the definition of a startup project for 6.1 or 6.2 mission funding within the organization. In addition to providing a pathway for the development of novel and high-quality research projects by providing support for the most innovative and often speculative ideas, this program is instrumental in enhancing the recruitment and retention of outstanding scientists and engineers. The creative atmosphere fostered in this manner is essential to the identification of emerging operational concepts and technology thrusts for the future.

7 Future Army Research Areas of Emphasis

The Army transformation will rely on basic research that may provide unexpected and revolutionary technologies that can further enhance the capabilities of future Army forces or, in extreme cases, fundamentally impact the systems, designs, and operational concepts on which these forces will be based. Although the project seeks major breakthroughs in technology, the synergy among currently developing research and technologies must be exploited to achieve revolutionary effects for the Objective Force.

The Objective Force project has identified systems to provide perspective to the basic research community in imagining where basic research-derived technologies may be applied in about the year 2025. They include:

POTENTIAL TECHNOLOGY AREAS FOR ENABLING THE OBJECTIVE FORCE

Hybrid power systems

Logistics efficiencies (ultra reliability, fuel efficiency, weight reduction)

Human engineering and cognitive engineering

Signature control (including counters)

Protection schemes for land systems (including active protection)

Advanced materials

Affordable precision and alternative lethality means

Alternative propellants

Nonlethal capabilities

Vaccines and drugs for infectious disease and CB protection

Human physiological knowledge bases, linked to physiological and performance modeling

- Situational awareness
- Global maneuver platforms
- Advanced airframe heavy lift/tactical utility lift
- Future fighting ground craft
- Autonomous and semiautonomous unmanned systems (air, ground, sensors)
- "Living Internet" with mobile, non-line-of-sight communications
- Assured intelligence, surveillance, and reconnaissance
- Soldier as a system.

The Army will continue to leverage and provide support to the technology efforts by the other services, academia, and commercial industry that support Objective Force capabilities. The Army will direct basic research dollars toward those Army-unique technologies that are critical to Objective Force capabilities.

8 Army Strategic Research Objectives

STRATEGIC RESEARCH AREAS

Biomimetics
Nanoscience
Smart materials and structures
Information technology
Intelligent systems
Compact power sources

In an effort to provide additional focus for the basic research program, the Army has defined nine SROs. These SROs represent major multidisciplinary research themes to achieve significant technological advancement through "systems engineering" at the basic research level. SROs represent areas of stable, sustained investment over a long term (5–10 years) to achieve technology enablement. Currently, the investment in SROs represents approximately 25 percent of the Army's basic research program. The Army has established a goal of increasing this to 40 to 50 percent by FY03 to increase the long-term focus of the program. Six of the Army SROs are also components of the DoD Strategic Research Areas. These SRAs were defined in coordination with the other services and agencies. A detailed description of the nine Army SROs follows.

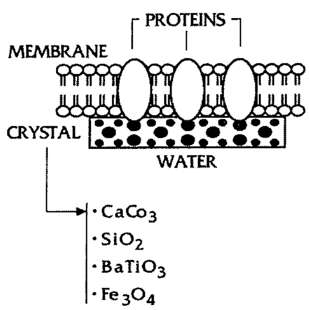
a *Biomimetics*

Objective. Enable development of new structural and functional materials and technologically innovative approaches toward sensing and information processing, with product and process lessons from nature contributing to design principles, performance capabilities, and manufacturing possibilities.

Approach. Biomimetics seeks to benefit from the direct manipulation of a process of biological origin or from engineered exploitation that derives a product or process design or function from a naturally occurring system. The overall approach is one that incorporates in a wholly integrated manner the most advanced and diverse conceptual and experimental tools of a number of scientific disciplines, including biology, materials science, chemistry, physics, mathematics and computer sciences, and electronics. Numerous materials occurring in biological systems exhibit remarkable properties. Uniquely, these materials derive their functionality from fabrication processes composed of several levels of self-assembly involving molecular clusters organized into structures of different length scales. Some of these materials are able to effect exceptionally efficient transfer of mass, charge, and energy over a very wide range of performance durations, or to provide unique supportive and protective structures. Biological systems also have exquisite and highly integrated sensing capabilities that allow rapid and selective recognition and signal processing that can detect and classify target molecules, men, or machines in

noisy and cluttered environments. Sensors designed using biological principles offer the possibility of novel classes of sensors that are far more sensitive and rapid than anything available today.

Military Potential. Rapidly emerging advances in this very young area of scientific endeavor show substantial promise to affect a number of Army applications. Contributions may include tough, lightweight composites for armor, chemical detection applicable to explosives and nerve agents, novel fibers for individual soldier protection, and catalysts for both synthetic and degradative purposes. Potential Army applications are noted in Figure V–2.

Lessons From Nature	*Mimic Nature—Biomimetics*	*New Advanced Materials*	*Army Systems*
Seashell Formation by Crystalization	• Micro-Layer Polymers	• Food Wrap • Armor	SOLDIER • Armor • Helmet • Goggles • Power • CBN • Food
	• Synthetic Nacre	• Smart Films • Wear Resistant	
	• Nano Mineralization	• Chemical Detection • High Energy Density Storage	STRUCTURAL • Vibration • Armor • Insulation • Wear
	• Synthetic Macro-Molecules	• Quantum Well Films • Non-Linear Optics • Nano-Magnetics	FUNCTIONAL • Power • Displays • MEMs • Memory
	• Transduction Elements	• pH Control	SOCIAL/ECONOMIC • Drugs • $ Savings • Explosives • Bio-friendly

- POC: Dr. Robert Campbell, ARL/ARO
- Funding: OSD MURI, SBIR, ARL/ARO, NSC
- Army Players: ARL/ARO, NSC

Vision:

Novel synthetic materials, processes, and sensors through exploitation of nature's design principles

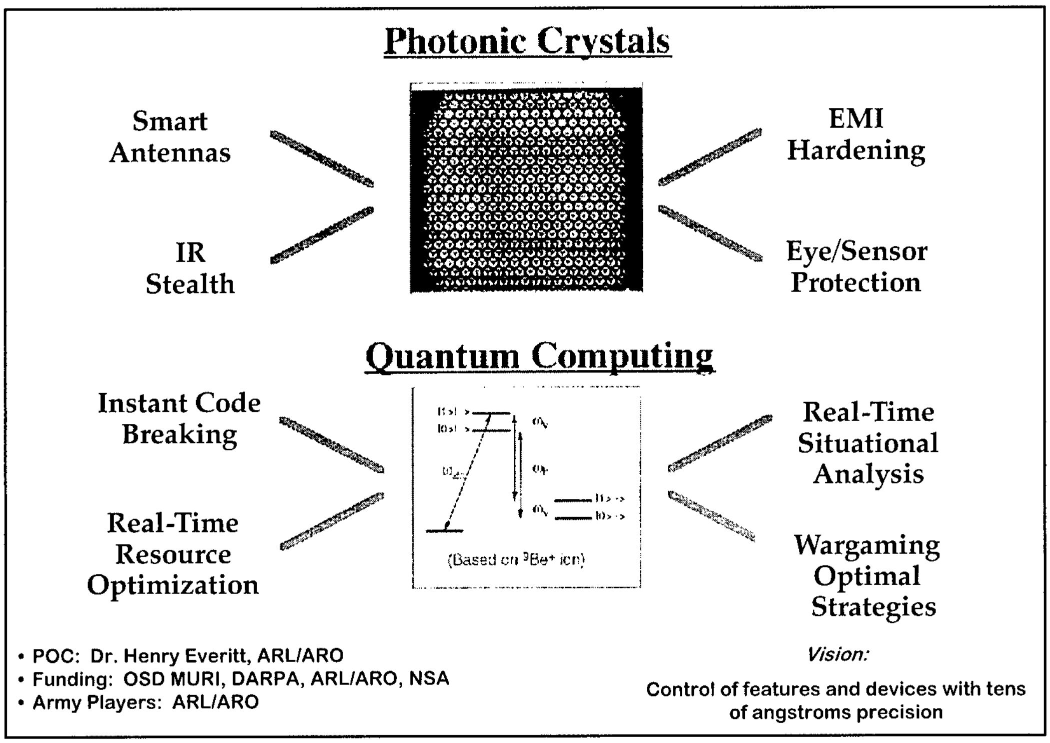
FIGURE V–2. BURGEONING APPLICATIONS OF BIOMIMETICS FOR THE OBJECTIVE FORCE

b *Nanoscience*

Objective. Achieve dramatic, innovative enhancements in the properties and performance of structures, materials, and devices that have controllable features on the nanometer scale (i.e., tens of angstroms).

Approach. Army support for nanoscience research is focused on creating new theoretical and experimental results involving atomic-scale imaging methods, subangstrom measurement techniques, and fabrication methods with atomic control that will provide reproducible material structures and novel devices. It also includes direct investigations of phenomenological evolution that is dominated by size effects or quantum effects. These quantum effects may, in turn, be used as the basis for fundamental new capabilities or for enhancing the performance of existing devices. Similar control over the electromagnetic propagation in nanostructured materials may allow for more precise control of microwave, infrared, and visible radiation. Scientific opportunities include understanding new phenomena in low-dimensional structures, nucleation and growth, self-organizing materials, site-specific reactions, and 3D nanostructural materials.

Military Potential. The ability to fabricate structures affordably at the nanometer scale will enable new approaches and processes for manufacturing novel, more reliable, lower cost, higher performance, and more flexible electronic, magnetic, optical, and mechanical devices. Recognized commercial applications of nanoscience include ultrasmall, highly parallel, fast computers with terabit nonvolatile random access memory and teraFLOP speed, image information processors, low-power personal communication devices, and high-density information storage devices. Army interest in nanoscience research includes lasers and detectors for weapons and countermeasures, optical (IR, visible, UV) sensors for improved surveillance and targeting, integrated sensor suites for CB agent detection, catalysts for enhancing and controlling energetic reactions and decontamination, and synthesis of new compounds (e.g., narrow-bandgap materials and nonlinear optical materials) for advanced electronic, magnetic, and optical sensors. Of particular interest are quantum computation for codebreaking, resource optimization and wargaming, and photonic band engineering for sensor protection, powerful radar, and low observables (Figure V–3). These devices exploit exciting properties of nanoscale materials not predictable from macroscopic physical and chemical principles.



A transmission electron micrograph of X3-nm-diameter gold clusters encapsulated by dodecanethiol that self-assembled into this array when deposited on a thin flake of molybdenum disulfide.

FIGURE V–3. NANOMETER-SCALE MICROGRAPH

c *Smart Materials and Structures*

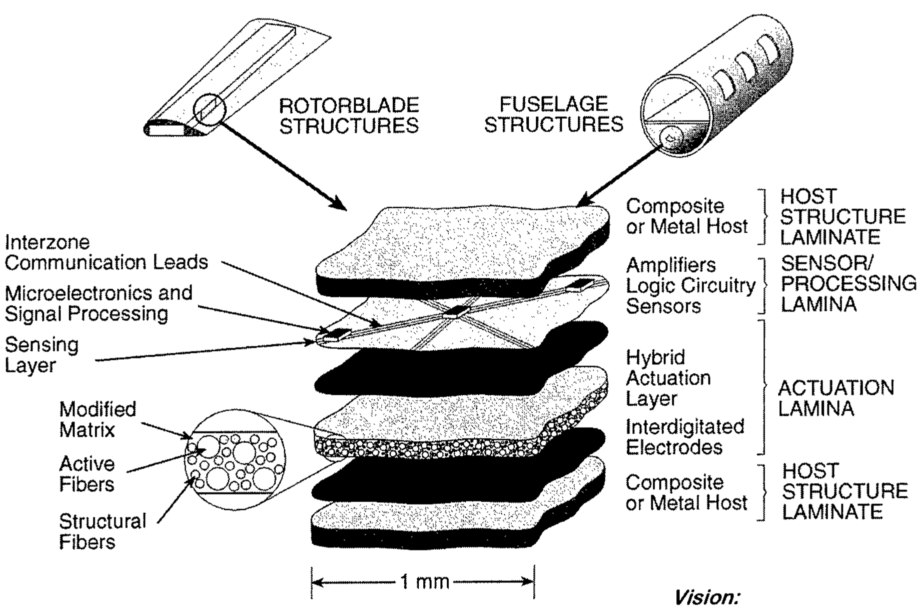
Objective. Demonstrate advanced capabilities for modeling, predicting, controlling, and optimizing the dynamic response of complex, multielement, deformable structures used in military and civil structures, land vehicles, weapons, and rotorcraft.

Approach. Smart structures offer significant potential for expanding the effective operations envelope and improving certain critical operational characteristics for many Army systems. Key

characteristics of smart structures include embedded or bonded actuators or sensors linked to a controller responsive to external stimuli to compensate in real time or quasi-real time to counter undesirable effects or to enhance overall system performance. To help realize the full potential of smart structures in military systems, the Army's basic research program is supporting fundamental investigations that address active and passive structural damping techniques, advanced actuator concepts capable of providing greater forces and displacements, embeddable and nonintrusive sensors for structural health monitoring, and active actuator materials (e.g., piezoelectric, electrostrictive, and magnetostrictive materials; shape-memory alloys; magnetorheological fluids). Also being pursued are important studies focused on new fabrication processes for actuators and sensors on the mesoscale (micrometer- to millimeter-scale), computationally accurate and efficient constitutive models for smart materials, advanced mathematical models for nonconservative and nonlinear structural and actuator response, development of hybrid structural optimization schemes, robust hierarchical control with distributed sensors and actuators, and concurrent, integrated structural design and control methodologies.

Military Potential. Potential military applications of smart structures include shock isolation and machinery vibration, including vibration control and stability augmentation systems in rotary-wing aircraft to extend structural fatigue life and reliability; barrier structures providing improved protection against CB agents; structural damage detection and health monitoring systems; more accurate rapid-fire weapon systems; fire control; battle damage identification and assessment; and control of active, conformal, load-bearing antenna structures, phased arrays, and broadband spiral antenna systems (Figure V–4).

Mesoscale integration of sensors, actuators, controls for rotorcraft structures:
- 80% reduction in vibratory hub loads
- Significant reduction in internal/external noise
- Increased performance
- Significantly reduced maintenance, logistics



- **POC: Dr. Gary Anderson, ARL/ARO**
- **Funding: OSD MURI, ARL/ARO**
- **Army Players: ARL/ARO, AMRDEC**

Vision:

Dynamic control and response of complex vehicles and systems; vibration and noise reduction

FIGURE V–4. SMART COMPOSITE ACTUATOR CONCEPT AND ARMY APPLICATIONS

d *Mobile Wireless Communications (Supports Information Technology SRA)*

Objective. Provide fundamental advances enabling rapid and survivable communication on-the-move (COTM) of large quantities of multimedia information (speech, data, graphics, and video) from point to point, and broadcast and multicast over distributed mobile wireless networks for heterogeneous C^3I systems.

Approach. Multihop packet radio network protocol research is conducted to provide COTM; integrate cable, satellite, and mobile wireless heterogeneous networks; and maintain connectivity, access, routing, and quality of service for multimedia communications in the highly dynamic network topology conditions on the battlefield. Research on adaptive coding and modulation is conducted to maximize power and spectrum efficiency and optimize signaling and receiver design to achieve best data throughput in the rapidly changing link conditions and network topology. Adaptive antenna array processing research for null- and beam-steering, diversity combining, and spectrum reuse to enable increased capacity with lower and reduced probability of intercept and jamming is conducted. RF device, circuit, and system research is conducted to reduce power loss. Modeling and simulation research is performed to increase the accuracy of performance prediction and adaption, mitigate cosite interference, and improve network simulation capability.

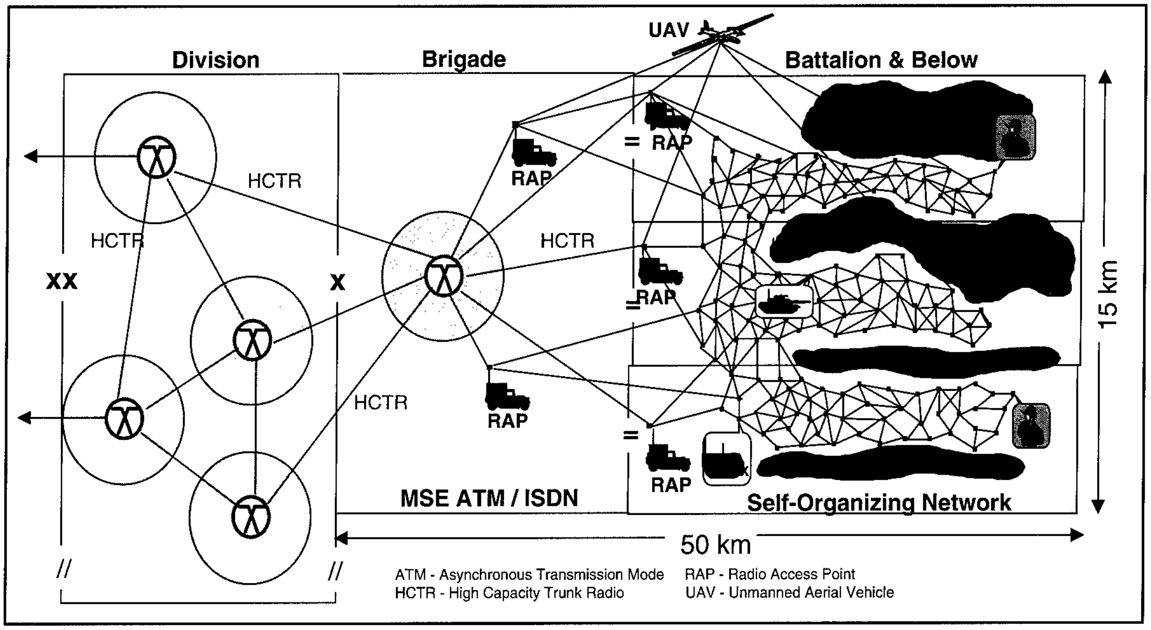
Military Potential. Research in this area provides the technology for establishing and maintaining mobile wireless network COTM under the harsh and highly dynamic conditions of modern battlefields. Civil networks have a quasi-static fixed topology, while the military COTM network topology may be continuously and rapidly changing. As a consequence, the military channel and network routing and connectivity are more complex and dynamic. Timely arrival of messages is highly critical to military operations. Networks can have no single points of failure and must be self-organizing to be survivable. Research is needed to significantly improve the throughput, efficiency, performance, survivability, and security of complex mobile wireless networks critical to the success of the future Objective Force's highly mobile operations. Advances in mobile wireless communications will greatly increase the capacity, reliability, and survivability of the Army's battlefield information distribution systems (Figure V–5).

e *Intelligent Systems*

Objective. Enable development of advanced systems capable of sensing, analyzing, learning, adapting, and functioning effectively in changing or hostile environments until completing assigned missions or functions.

Approach. Intelligent systems offer exciting new possibilities for conducting many types of military operations, ranging from reconnaissance and surveillance activities to a variety of specialized combat operations. Intelligent systems typically consist of a dynamic network of agents interconnected via spatial and communications links that operate in uncertain and dynamically changing environments using decentralized or distributed input and under localized goals that may change over time. The agents may be people, information sources, or automated systems such as robots, software, and computing modules.

Military Potential. Intelligent systems must be capable of gathering relevant, available information about their environment, analyzing its significance in terms of assigned missions and functions, and defining the most appropriate course of action consistent with programmed decision logic. Achieving these objectives requires integration of significant scientific and technological



Seamless mobile wireless communication is the underpinning of many of the capabilities for the Objective Force and the *Joint Warfighting Science and Technology Plan.* In the 21st century, DoD must field a robust, mobile, wireless communication system that has the capability to provide COTM to warfighters, and integration of heterogeneous network protocols, including commercial protocols such as ATM, ISDN, TCP/IP, and multimedia (video, voice, and data) services. This SRO addresses these issues as well as the need to provide fully distributed, self-organizing networks with mobile-to-mobile connectivity, smart antennas for spatial reuse of channels, robust compression for wireless channels, and operation with minimal energy to extend battery life.

FIGURE V–5. MOBILE WIRELESS COMMUNICATIONS

advances in many diverse fields, including electronics, physics, mathematics, materials science, biology, computer science, cognitive and neural sciences, control theory and mechanisms, and electrical and systems engineering. Critical areas of research being pursued include the design of multiagent systems, representation of hierarchical perception systems, advanced models for learning and adaptation, development of effective frameworks for representing and reasoning with uncertainty, and new computational paradigms for accommodating imprecision in human-centered systems. The numerous potential military applications of intelligent systems include unmanned vehicles (air and ground), smart weapons, real-time C^2 systems for future battlefields, and CB defense systems (Figure V–6).

f *Compact Power*

Objective. Identify and exploit new concepts in portable power, especially in fueled systems, to increase the energy density and lower the cost of subkilowatt power sources.

Approach. The energy density of typical fuels exceeds that of batteries by 10–100 times. Lightweight energy converters, using air as the oxidizer, are the key to exploiting the high-energy content of such fuels. Converter technologies under study include fuel cells, microturbines, thermophotovoltaic systems, and alkali metal thermal-to-electric converters.

Military Potential. Small, lightweight energy converters may be used in a variety of configurations. Hydrogen/air fuel cells can now be made small enough (a 50-watt fuel cell stack is a cube 6 cm on a side) to fit in battery cases and serve as long-lived, refuelable, direct replacements for batteries. Microturbines hold the promise of providing up to 20 times the energy storage of a battery system of similar weight (Figure V–7). Alternatively, for applications requiring air-

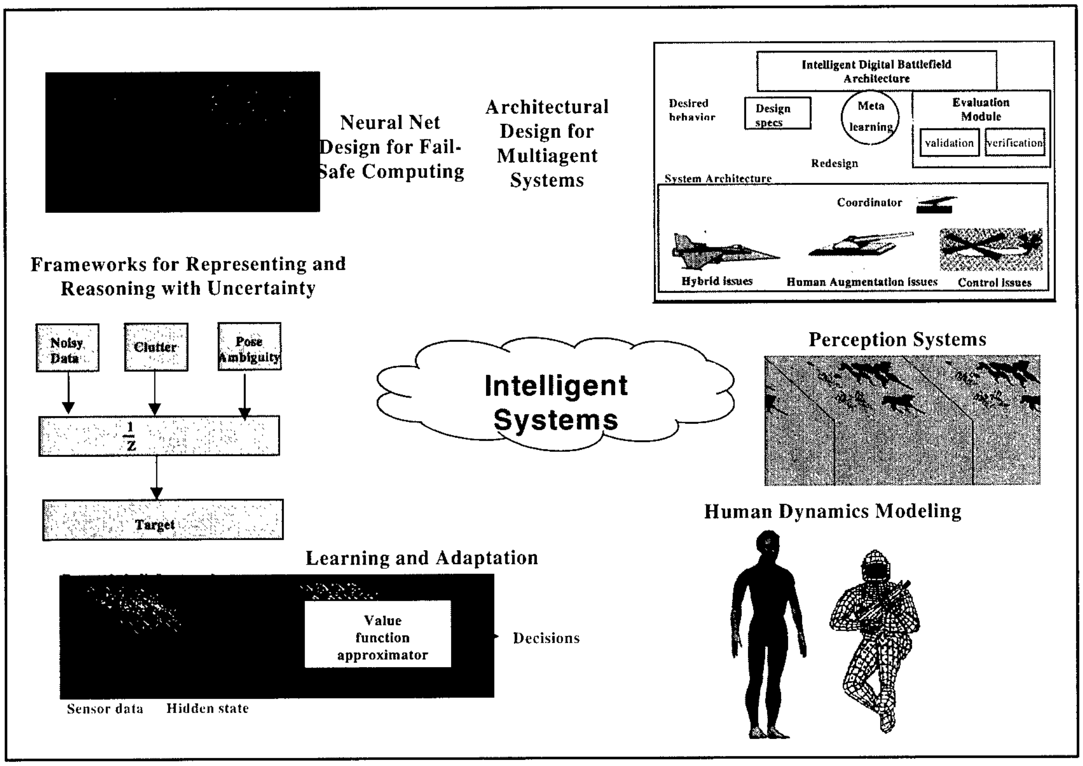


FIGURE V–6. INTELLIGENT SYSTEMS

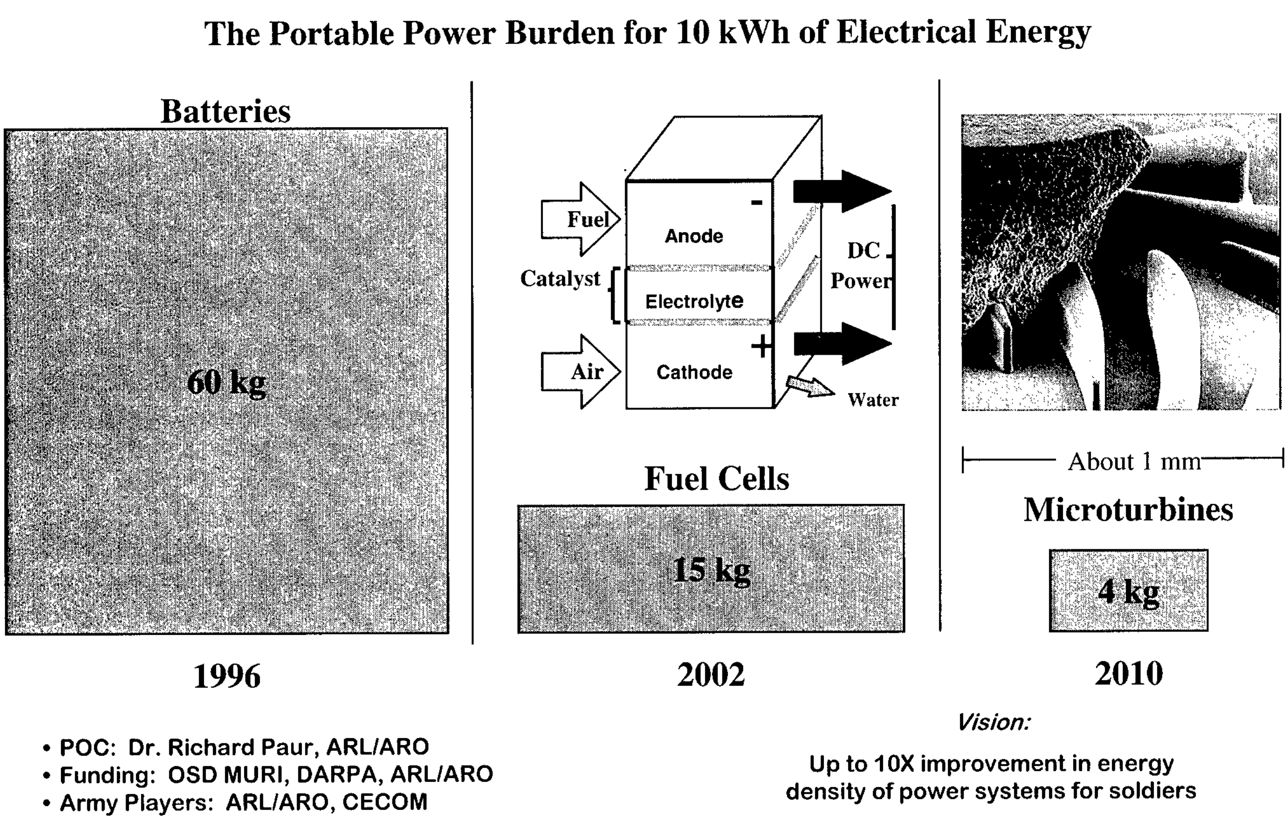


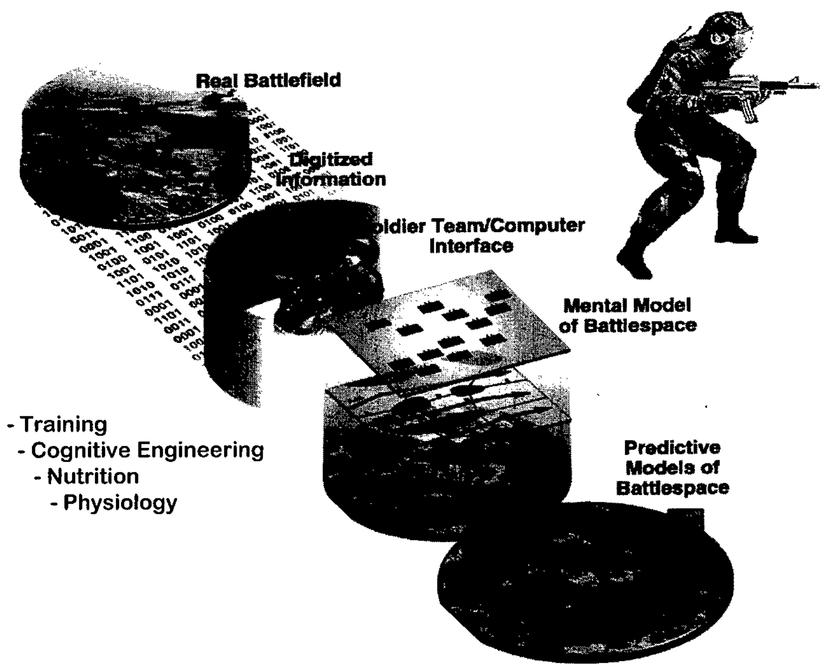
FIGURE V–7. COMPACT POWER SOURCES

independent operation, it may be desirable to use the small converters as lightweight, portable battery chargers. Many applications may be best supported with hybrid systems consisting of high-discharge-rate, low-energy-density, rechargeable batteries that can provide high peak powers and that are recharged by small (a few watts) fueled battery chargers running at low power on a nearly continuous basis. The hybrid systems should be able to provide the ease of distribution of battery power combined with the high-energy density of fuels in long-lived systems with low life-cycle costs.

g *Enhancing Soldier Performance*

Objective. Achieve significant enhancements in the cognitive and physical performance of soldiers in combat (e.g., heightened vigilance and awareness, improved information processing, decisionmaking and task performance, enhanced physical and mental endurance, quickened responses, augmented mobility) through advanced understanding and augmentation of human behavioral and physiological processes.

Approach. The future Army will have new missions, doctrine, and technology. For soldiers to perform effectively, a better understanding of soldier behavior and the interface of soldiers and their systems is needed. Figure V–8 shows the importance of the soldier interface toward the development by the commander of an accurate mental model of the battlespace. This SRO exploits advanced knowledge from the fields of psychology, physiology, biomechanics, and nutrition to develop a comprehensive understanding of how soldier performance is most effectively enhanced and maintained in combat.



- Lead: Dr. Michael Drillings, ARI
- Funding: ARI, MRMC, ARL/ARO, NSC
- Army Players: ARI, MRMC, ARL/ARO, NSC

Vision:

Psychological and physiological interventions to enhance the mental and physical agility of future soldiers and leaders

FIGURE V–8. ENHANCING SOLDIER PERFORMANCE

Military Potential. Effective combat performance, ranging from high-level command and control processes down through the individual combatant task execution, is highly dependent on the degree to which the soldier's behavioral and physiological functions can be trained, supported, and maintained in an intense and environmentally hostile setting. Individual response to technological advancements—such as digital information systems, simulation and modeling capability, decision aids, sensors, and ergonomic and erogenic aids—must be optimized to extend the soldier's capabilities on the battlefield. Specific aspects of soldier performance must be maximized by interventions that can be tailored to be effective under intense and hostile conditions. To realize the full benefit of investment in these areas, the Army must better understand the factors and interactions that determine how these human processes operate—particularly their interaction with advanced technology in a stressed combat environment—as well as the additional risk of overloading the soldier with information.

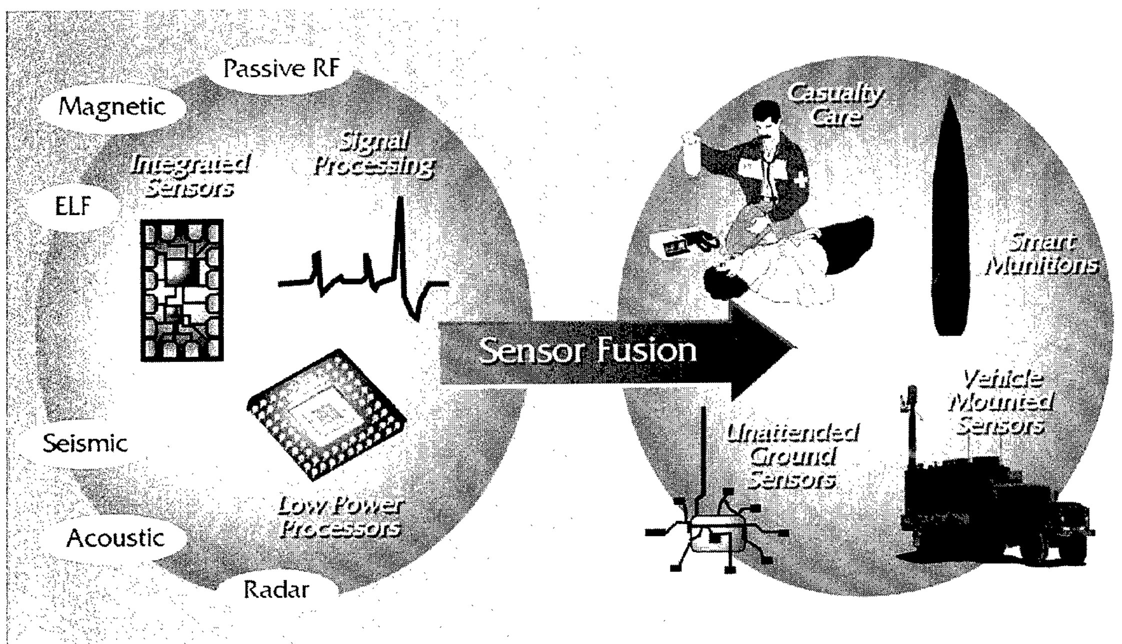
h *Microminiature Multifunctional Sensors*

Objective. Realize miniaturized, multifunctional, and multispectral sensors and sensor arrays based on novel manmade and biological material systems; on techniques for intelligent interpretation, display, and transmission of imagery; and on new fabrication techniques to provide the capabilities to monitor, image, track, predict, fuse, and report information in real time.

Approach. To realize such application-specific microminiature multifunctional sensor systems, research must be conducted to provide a leading technology base for the fabrication of novel material structures with the desired electronic, optical, and material properties. This technology base must facilitate the atom-by-atom and layer-by-layer growth of manmade structures with tailored physical properties. In addition, research must address the integration of such novel structures into sensor systems satisfying stringent constraints on weight, size, reliability, and low power consumption, as well as novel miniature power sources such as microturbine-based generators. To achieve large-scale integration of sensors and components, research is needed to provide a fundamental understanding of microstructure characteristics and processes for modifying and controlling interfaces and the interphase nanostructure as well as the electromagnetic and dynamic mechanical properties between dissimilar materials. To ensure availability of sensors for diverse applications, research in materials science is needed to advance the technology base for intelligent materials, photonic bandgap materials, and dimensionally confined material systems. To realize optimum system and device integration as well as manufacturability, research efforts must address issues underlying packaging, calibration methods, architectures for on-the-fly reconfigurability, system redundancy, and system self-repair. Research is needed to define networking techniques for fault-tolerant, environmentally tailorable, rapidly reconfigurable sensor arrays with expendable components. Research on CB sensors must address issues underlying measurement repeatability, fragility, and surface functionality. Research must be conducted to provide for detection of weak signals covering vast spectral ranges, including the electromagnetic bands of microwave, MMW, terahertz, IR, visible, UV, and x-ray radiation. Moreover, research must address the detection of weak acoustic signals and the exploitation of biological capabilities that are now known to be so precise that they can detect the presence of a single atom or a single photon of light.

Military Potential. The integration and fusing of hyperspectral sensors operating in different modalities will lead to new levels of detectivity and multifunctionality. Application-specific microminiature sensor suites will provide the basis for expendable "guardian angel" battlefield intelligence systems essential for military operations in urban terrain (MOUT)-like environ-

ments as well as for telemonitoring the status of the individual soldier (Figure V–9). Advanced compact, multifunctional sensors will also provide the basis for intelligent weapon systems, tunable lethality, compact CB detection systems, and reliable detection of mines and weapons; and will perform indispensable roles in achieving information dominance. All of these microminiature multifunctional sensor systems must be tailor made, possibly with biological or biologically inspired components, for the specific applications at hand. They will also have to satisfy demanding military specifications, including low cost, high reliability, low weight, small size, low energy consumption, and compatibility with mobile, wideband wireless communications systems incorporating state-of-the-art information protection technology.



- Lead: Dr. Mike Stroscio, ARL/ARO
- Funding: ARL/ARO, OSD MURI
- Army Players: ARL/ARO, CECOM, AMRDEC

Vision

Multifunctional microminiature sensors and rapidly reconfigurable sensor arrays to provide comprehensive situational understanding

FIGURE V–9. MICROMINIATURE MULTIFUNCTIONAL SENSORS

i *Armor Materials by Design*

Objective. Acquire fundamental knowledge and science-based methodology for the hierarchical design and integration of materials pertinent to the future development of armor material systems and affordable structures that incorporate signature control, novel mechanisms for energy absorption and dissipation, multithreat protection, and major reductions in weight and bulk.

Approach. Integrating ballistic, blast, thermal, EM, and NBC protection with stealth, signature control, sensor, and communication systems into primary components for future Army systems demands novel materials as well as a thorough understanding of the micromechanics of dynamic failure processes and system performance requirements. Traditional approaches of improving armor effectiveness and signature management are not compatible with reducing

weight or bulk and, in the case of personnel armor, providing multiple threat protection. Ongoing Army research and breakthroughs in the integrated design of lightweight integral composite armor, nanolaminate polymer/ceramic hybrid materials, functionally graded metal/ceramics, and constrained ceramic/metal systems are very encouraging in offering potential lighter weight armor solutions. Likewise, research on electrochromics, photonic bandgap materials, and superlattice structures shows promise for developing unique EM-responsive materials for signature management and control. New experimental techniques, basic understanding of interfaces and interphases between dissimilar materials, advanced theoretical concepts, and sophisticated computational approaches are being exploited to (1) identify critical combinations of dynamic material properties and related material characteristics that determine performance, and (2) help establish guiding principles for the design, fabrication, and evaluation of integrated, multifunctional material systems. Research programs aimed at understanding dynamic failure processes and physical constraints of conceptual material designs with full knowledge of their atomic, microstructured, and macrostructural characteristics are expected to lead to major improvements relative to present-day armor and signature management approaches, and to pave the way for radically improved materials and functionally integrated armor packages.

Military Potential. The Army will need lighter weight, more robust, and integrated armor materials and systems to meet future requirements for speed, mobility, and deployability of weapon platforms and to enhance survivability and battlefield effectiveness of combat personnel in the face of a widening range of more lethal and countering threats. Potential military applications include the Objective Force, future combat land systems, advanced aircraft, individual protection, transparent armor, and hardened shelters. Conceptually, armor is expected to evolve from heavy armor and appliques to lightweight integral armor systems and more specialized multifunctional, functionally graded, and transparent armor materials (Figure V–10).

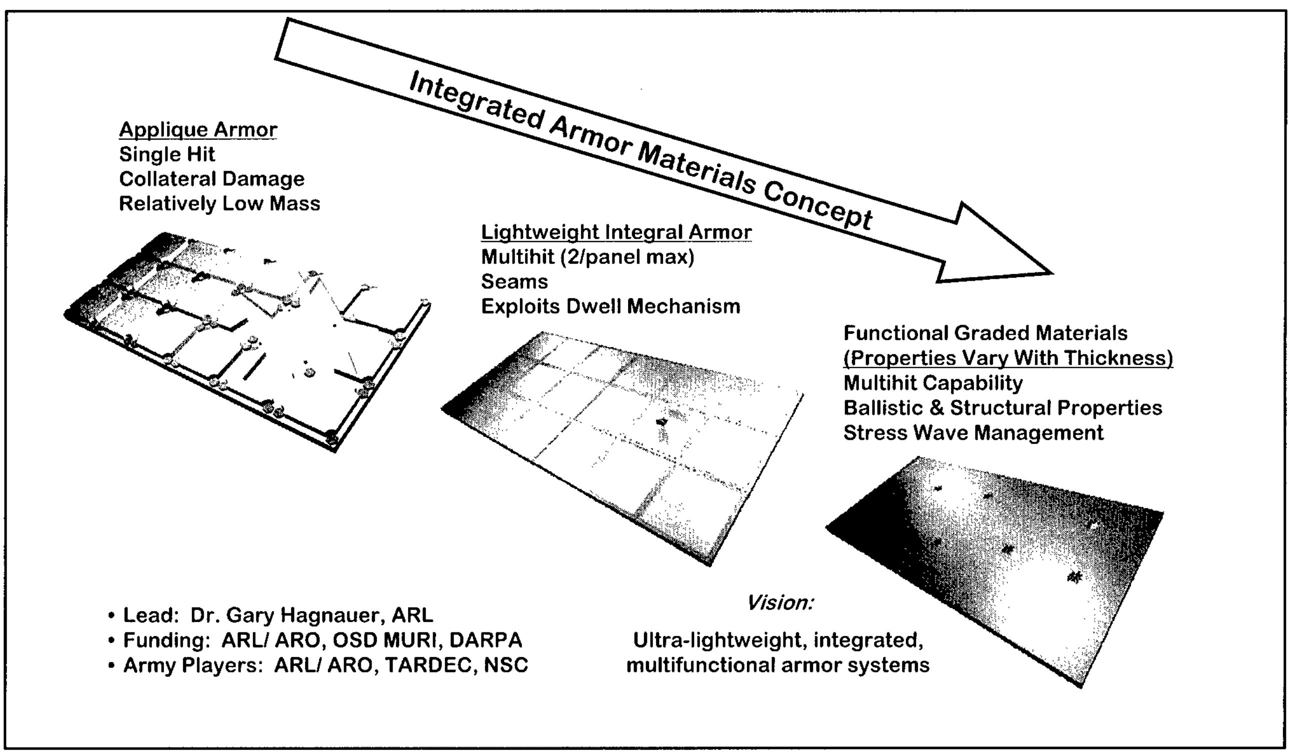


FIGURE V–10. ARMOR MATERIALS BY DESIGN

In managing its basic research program, the Army is giving special attention to these nine SROs to help ensure that their potential can be realized through subsequent technology and system development efforts. Identification of additional areas and objectives will be sought in continuing reviews of basic research activities. Representative specific research goals associated with the SROs described above are provided in Table V–6.

TABLE V–6. BASIC RESEARCH GOALS ASSOCIATED WITH STRATEGIC RESEARCH OBJECTIVES

2005	2010	Objective Force
	BIOMIMETICS	
Characterization of enzymatic breakdown of chemical threat agents at molecular level Definition of role of biomolecular recognition-based interactions in superstructure formation Novel optical processing materials	Foundation for mimicking active site mechanism of catalysis Predictive rules & methods for biomimetic hierarchical nanomaterials fabrication Advanced capabilities for sensing biological & trace chemicals	Robust biomimetic catalytic system developed for chemical agent decontamination Manipulation of macromolecular properties to achieve optimal performance Novel process for ceramic composite manufacture
	NANOSCIENCE	
Efficient microwave radar Broadband optical limiting High-bandwidth communication	Hybrid CB sensors IR low observables Terabit, teraFLOP computers	Rapid CB decontamination Atom interferometer gyroscope Quantum computing
	SMART MATERIALS & STRUCTURES	
Demonstration of up to 60-dB vibration reduction using shaped actuators & adaptive control algorithms Achievement of MEMS wireless communications in a rotorcraft flight structure Demonstration of new impact-energy-absorbing active materials	Demonstration of low-cost, self-tuning structural vibration damping treatment with integrated power sources & signal processing capability Demonstration of addressable optical fiber sensor arrays to measure temperature & strain for damage detection in composite structures Achievement of high-force & high-displacement actuators fabricated from improved active materials	Demonstration of smart, conformal, load-bearing multifunctional antenna structures for rotorcraft & land vehicles Realization of active material-based rotor blade control for stealthy, long-range, & highly maneuverable rotorcraft Achievement of high-precision controlled pointing & tracking techniques for accurate weapon systems for rotorcraft & land vehicles
	MOBILE WIRELESS COMMUNICATIONS	
Limited mobile COTM packet radio networks Limited multimedia services over wireless networks Aerial relay to maintain connectivity Power-efficient RF system design	Conformal antennas for vehicles Multifunction antennas for communications Video for mobile wireless networks Aerial & satellite support of mobile COTM networks Programmable communication devices	Adaptive, self-organizing networks Full internet compatibility Smart antennas for portable transceivers Extremely low probability-of-intercept signals Personal communication devices
	INTELLIGENT SYSTEMS	
Establishment of fundamental roles played by hierarchical organization, compositionality, & learning in IS design Definition & characterization of simulated battlefield environments for testing IS methodologies Demonstration of intelligence augmentation of human-centered systems, with emphasis on cognitive issues	Establishment of a framework for integrating high- & low-level aspects of intelligent systems Exploitation of framework in devising next-generation control algorithms & designing prototype systems (e.g., those that have integrated vision & control systems) Definition & characterization of integration of intelligent systems into larger network of systems (e.g., C^3I)	Achievement of new understanding of learning styles in the human brain relevant to the design of intelligent systems Demonstration of useful performance characteristics of fully autonomous intelligent systems Demonstration of advanced sensor & control capabilities of fully autonomous intelligent systems
	COMPACT POWER	
Demonstration of compact direct methanol fuel cells via low-crossover membranes & methanol-tolerant catalysts Demonstration of liquid-fueled microturbine generator with efficient power electronics (>10 W/cm^3) Demonstration of quiet liquid-fueled thermophotovoltaic power sources (250 W/kg)	Demonstration of 300-W compact fuel cell that operates on logistics fuels at moderate temperatures Demonstration of liquid-fueled microturbine generator with efficient power electronics (>100 W/cm^3) Demonstration of high-efficiency (>25%) logistic fueled alkali metal thermal-electric converter power system	Low-cost, highly reliable fielded power systems made possible by better materials design & improved manufacturing processes Use of biotechnology to produce useful quantities of fuel from renewable resources

TABLE V–6. BASIC RESEARCH GOALS ASSOCIATED WITH STRATEGIC RESEARCH OBJECTIVES (CONT'D)

2005	2010	Objective Force
ENHANCING SOLDIER PERFORMANCE		
Development of methods to train digital tasks for better retention Protection of hearing without loss of situation awareness Development of imagery & data fusion concepts that decrease crew workload	Integration of improved training methods into intelligent tutoring systems Integration of high-data-rate acoustic displays & hearing protection Development of automated stress management advisories	Development of basis for seamless training, assessment, & remediation within operating environments Integration of modular sensory augmentation & protection for dismounted & mounted soldiers Development of information management suite that controls stress levels by optimizing sensory route
MICROMINIATURE MULTIFUNCTIONAL SENSORS		
Miniature uncooled, unattended IR detectors 2-color FPA staring imagers Application-specific microlens arrays for FPAs MEMS-based acoustic, seismic, optical, & magnetic sensors for unattended use & extended periods Engineered biomolecular material for high quantum efficiencies in detection devices	3-color, 2048 x 2048 TE-cooled staring imager for visible/SWIR/MWIR/LWIR with integrated micro-optics, polarization sensing, up to 480-Hz frame rate Real-time processing & display of integrated sensory data from unattended IR, optical, magnetic, acoustic sensors, olfactory sensors, & MEMS sensors based on biochemical tranducers Single-photon detectors Self-correcting MEMS accelerometers	Intelligent interpretation & display of integrated sensory data Single-molecule detectors for CB applications Integrated interpretation & understanding of data from diverse platforms & arrays of mixed functionality sensors, including MEMS sensors, wideband sensors of radiation exploiting micro-optics, & multifunctional CB sensors based on engineered biomolecular materials
ARMOR MATERIALS BY DESIGN		
Novel defeat mechanisms & damage/failure mechanism models Novel processing technologies for armor transparencies & integral/multicore composite armor Lightweight, damage-tolerant polymer/ceramic/metal hybrid material systems Conformal coatings with variable/adjustable EM emissivity/reflectivity in the IR band	Integration of length-scale models to armor design Multifunctional, hierarchically integrated structural composite & transparent armor systems Amorphous/ultra-lightweight metals & hierarchical/microlaminate polymer/ceramic materials Flexible, conformal coatings/materials with tunable IR/visible emissivity/reflectivity & field-adjustable IR properties	Methodology for armor damage defeat/failure prediction against multiple/coupled field effects Basic guiding principles for the design of lightweight, multifunctional, & integrated armor structures Ultra-lightweight, multifunctional integrated personnel armor systems for multithreat protection Adjustable visible, IR, & MMW emissivity/reflectivity & smart, acoustic materials/structures for audio attenuation based on active feedback

9 Other Academic Leveraging

During times of diminishing budgets, increased leveraging becomes more necessary to help mitigate the impact of funding cutbacks on R&D programs. In addition to the preceding academic programs, the Army is significantly leveraging several other major academic institutions and consortia.

Industrial member fees, State of New Jersey funding, Rutgers University funding, and government grants fund the Center for Advanced Food Technology (CAFT) at Rutgers University. The Army's basic membership fee is leveraged by a factor of 60 in relation to the overall CAFT operating budget. Members, including the Natick Soldier Center (NSC), have an active role in selecting research projects for funding and monitoring their progress. CAFT work on stability factors for snack performance bars and new research on nutraceuticals complements in-house Army R&D.

The Oregon State University Consortium for High-Pressure Food Preservation is another example of the Army's great return on a relatively small investment. That center is being folded into the activities of the new Division of Nonthermal Processing of Institute of Food Technologists, which is currently chaired by an NSC scientist. Similarly, the Ohio State University Center for Non-Thermal Processing is being leveraged in its effort to move pulsed electric field food processing to commercialization, which will benefit the Army as well as the private sector with fresher tasting and higher quality rations with extended shelf stability. That center and its industrial partners were awarded an FY99 dual-use S&T project by the Army. The Ohio State

center has now merged with the National Science Foundation (NSF) Center for Advanced Processing and Packaging together with activities at the University of California at Davis and North Carolina State University.

The Army leverages considerably from the University of Massachusetts campuses at Lowell, Amherst, and Dartmouth. At Lowell, through the chemistry and physics departments and the Center for Advanced Materials, groundbreaking work is evolving on biologically derived electronic and photonic polymers and the development of nanoparticle-based organic solar cells. Lowell also supports the Army's efforts to produce novel permselective membranes as well as Natick's efforts to produce ceramics using biomimetic processing. The Army also participates at Amherst in the Center for Research in Polymers, where new polymers and polymeric materials are explored. Collaboration on producing high-performance fibers using wet spinning techniques is also being initiated between NSC and UMass Amherst. NSC has continued a student research experience program with Dartmouth whereby students from the Textile Science Department work on Army projects for college credit. Dartmouth is being further leveraged due to its research involvement with the National Textile Center.

Clarke University has been involved in investigating the diffusion of organic solvents in nanocomposite materials and permselective membranes using nuclear magnetic resonance. Northeastern University has conducted studies on mathematically modeling tear propagation at damage sites in woven fabrics as well as modeling optical limiting phenomena. In the area of nanotechnology, several new collaborations have been initiated, including one with Boston College that involves synthesizing and characterizing carbon nanotubes, and an effort with Clark University to produce and characterize nanoclay/polymer composites. Research on chemical agent decontamination is being conducted with Emory University, Kansas State University, and Harvard University.

In the biotechnology field, the Army is working with the University of New Hampshire on molecular interaction analysis and with the Universities of Rhode Island and Kentucky on agent detection and decontamination. Academic collaborations are expected to increase as solutions are sought using new technologies such as nanotechnology, biotechnology, and molecular modeling to produce lightweight materials for protection against ballistic threats, CB agents, and laser irradiation.

The airdrop program at NSC has been leveraged by work at Rice University with the Team for Advanced Flow Simulations and Modeling, the University of Connecticut, Worcester Polytechnic Institute, and Parks College of Saint Louis University. These efforts are focused on airdrop system modeling and experimental validation. The research involves use of high-performance computing assets and technologies based on the finite-element method to couple computational fluid dynamic and computational structural dynamic softwares to predict fluid-structure interaction phenomena associated with all airdrop systems. In addition, this collaborative research team has begun preliminary validations by comparing simulation results to ongoing concurrent wind and water tunnel experiments. Teaming with experienced universities has significantly reduced the time required to achieve these desired goals. In addition, the team frequently employs undergraduate students to assist in these airdrop system simulations, including cadets from the U.S. Military Academy and students from Boston University.

The NSC airdrop program also leverages the experimental facilities at Drexel University and the University of Massachusetts at Amherst to augment Small Business Innovation Research programs. The photonics and textile laboratories at Drexel are being used to develop a fiber-optics

measurement method to monitor the dynamic structural behavior of parachute fabrics and webbings. The biomechanics laboratory at the University of Massachusetts is investigating the landing dynamics of parachutists. These research programs are vital to the safety of the Army's airborne soldiers.

NSC and ARL hold a joint membership in the Northeastern University Center for Electromagnetics Research, which conducts broad-ranging research in EM waves and their interactions with materials. As a voting member of the center, NSC impacts the direction of ongoing and future research efforts and receives graduate school resources to support the needs of the Army, which benefits significantly from this leveraging.

NSC has continued and expanded its academic leveraging outside of the United States. The Army is benefiting from its interactions at universities in the United Kingdom, the Netherlands, and Finland. Collaborative research considering sensory attributes, acceptance factors, and consumer issues of food and clothing is ongoing with Bournemouth University in England, the University of Edinburgh in Scotland, Wageningen University in the Netherlands, and the University of Helsinki in Finland. Scientists from these universities have conducted research at NSC, have jointly published papers with NSC scientists, and have even involved themselves in Army fieldwork, all at minimal expense to the Army. In addition, they have hosted Army researchers at their institutions.

D EXECUTION—SCIENTIFIC RESEARCH AREAS

The Army has established a vigorous research program covering a wide range of disciplines to capture and exploit the new opportunities presented by research advances and discoveries. This program is executed primarily by university contractors and in-house laboratory and RDEC personnel, and maximizes the use of the initiatives discussed in Section C.

ARMY SCIENTIFIC RESEARCH AREAS	
Mathematical Sciences	Mechanical Sciences
Computer and Informational Sciences	Atmospheric Sciences
Physics	Terrestrial Sciences
Chemistry	Biomedical Research
Materials Science	Biological Sciences
Electronics Research	Behavioral, Cognitive, and Neural Sciences

Within a wide spectrum of research, 12 primary areas emerge that are of particular importance to tomorrow's Army:

1 Mathematical Sciences

a *Strategy*

Mathematics plays an essential role in modeling, analysis, and control of complex phenomena and systems of critical interest to the Army. Mathematical modeling is increasingly being identified as critical for progress in many areas of Army interest, and scientific tasks in these areas are frequently of significant complexity. As a result, researchers from two or more areas of mathematics must often collaborate and team with experts from other areas of science and engineering to achieve Army goals. Some examples of cross-cutting areas of research include the breakup of liquid droplets in high-speed airflow (for determinating the dispersion of chemical

or biological agents spilled from intercepted theater-range missiles), computational methods for penetration mechanics, and automatic target recognition.

An investment strategy meeting with participants from ARL/ARO, RDECs, Corps of Engineers Waterways Experiment Station (WES), Concepts Analysis Agency (CAA), Deputy Under Secretary of the Army (Operations Research) (DUSA(OR)), and academia identified several research areas that will have significant impact on future Army technologies. Research priorities recognized in five major areas are listed below.

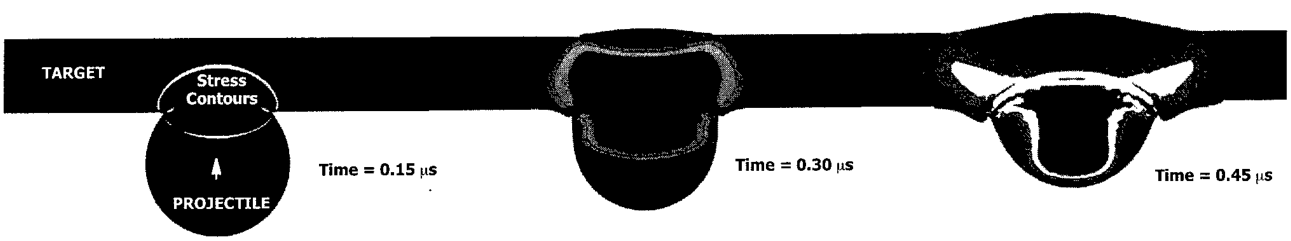
b *Major Research Areas*

Applied Analysis

- Fluid flow, including flow around rotors, missiles, and parachutes; combustion; detonation and explosion; two-phase flow; granular flow.
- Nonlinear dynamics for optics, dielectrics, electromechanics, and other nonlinear systems, and physics-based mathematical models of human dynamics.

Computational Mathematics

- Rigorous numerical methods for fluid dynamics, solid mechanics, material behavior, and simulation of large mechanical systems (Figure V–11).
- Optimization: large-scale integer programming, mixed-integer programming, and nonlinear optimization.



Numerical simulation of the impact of a tantalum sphere with a tantalum plate using a front tracking method that was developed with ARO funding. The sphere was originally traveling at 2 km/s. The contours are level curves of the total stress. Note that the method easily handles the large deformation of both the projectile and the target. This technology can be used for development of both armor and projectiles.

FIGURE V–11. NUMERICAL SIMULATION OF IMPACT AND LARGE DEFORMATION

Probability and Statistics

- Stochastic analysis and applied probability: stochastic differential equations and processes; interacting particle systems; probabilistic algorithms; stochastic control, optimization, and approximation; power processes; large deviations; simulation methodology; image analysis.
- Statistics: analysis for very large data sets or very small amounts of data from nonstandard distributions, highly multivariate datasets, Bayesian methods, Markov random fields, cluster analysis.

Systems and Controls

- Mathematical system theory and control theory: control in the presence of uncertainties; robust and adaptive control for multivariable and nonlinear systems; system identification and its relation to adaptive control, hybrid control, hybrid-infinity control, and nonholonomic control.

- Foundations of intelligent control systems: discrete-event dynamic systems, hybrid systems, distributed communication and control, intelligent control systems.

Discrete Mathematics

- Computational geometry, logic, network flows, graph theory, combinatorics.
- Symbolic methods: computational algebraic geometry for polynomial systems, discrete methods for combinatorial optimization, symbolic methods for differential equations, algorithmic methods in symbolic mathematics.

c *Potential Military Benefits*

With the change from a predictable large threat to numerous and often unpredictable regional threats, the need for more flexibility in Army systems and more rapid development of these systems increases. As the cost of physical experimentation increases, the role of mathematical modeling becomes more important. Mathematical modeling is a major factor in ensuring that a system is well designed and that, once built, it will work. In all of the following areas, mathematics is a fundamental tool required by the Objective Force and all future Army systems:

- Design of advanced materials and novel manufacturing processes
- Behavior of materials under high loads, failure mechanics
- Flexible and adaptable structures
- Fluid flow, including reactive flow
- Power and directed energy
- Microelectronics and photonics
- Sensors
- Automatic target recognition
- Soldier system enhancement: behavioral modeling, performance, mobility, heat-stress reduction, camouflage (visible, IR), chemical and ballistic protection.

2 Computer and Information Sciences

a *Strategy*

Computer and information sciences address fundamental issues in understanding, formalizing, acquiring, representing, manipulating, and using information. The advanced systems, including the software engineering environments and new computational architectures facilitated by this research, will often be interactive, adaptive, sometimes distributed or autonomous, and frequently characterized as intelligent. Computer-based systems that process information and transfer data and analysis among various Army commanders and units are essential for military success.

The computer science and software issues that arise in this context often require input from a number of subdisciplines of computer science, as well as from other disciplines. These areas include multisensor fusion, multi-image fusion, image understanding, language processing, distributed interactive simulation, multivariable and multiresolution methods for terrain modeling, scalable parallel algorithms, and algorithms for processing large-scale data. In these areas, computer and information sciences research is organized in a cross-cutting fashion to provide the expertise needed to accomplish the Army goal. Based on the recommendations from an investment strategy meeting among senior scientists from ARL, RDECs, TRADOC, DUSA(OR),

CAA, COE, and academia, research in the areas described below was determined to be important to the Army.

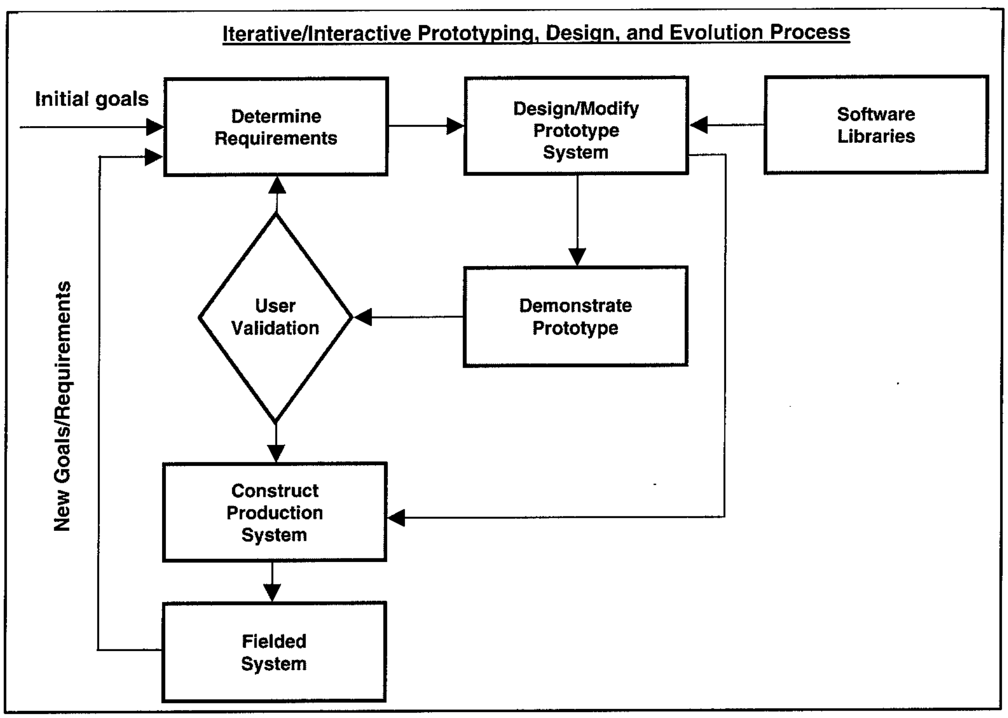
b *Major Research Areas*

Theoretical Computer Science

- Formal models underlying computing technology, optimization of input/output communication, new computing architectures, multiprocessing, parallel systems, and advanced architectures.
- Graph theoretic methods applied to parallel and distributed computation, models, and algorithms for the control of heterogeneous concurrent computing.

Formal Methods for Software Engineering

- Software engineering architectures: environments, tools, integrated tool sets (Figure V–12).
- Software generation: invocation of formal methods, software reuse.
- Software evolution: change, merging, documentation.
- Software reliability: validation, verification.



The iterative rapid prototyping process involves an "end-to-end" machine-based approach to future software engineering enablement and software life-cycle management. This paradigmatic alternative to "programming" allows for the rapid incremental building of large-scale systems and their principled evolution.

FIGURE V–12. SOFTWARE AND KNOWLEDGE-BASED SYSTEMS

Knowledge-Based/Database Sciences

- Heterogeneous data structures: mediators, complex reasoning.
- Machine learning: methodologies for uncertainty, incompleteness, information recognition, content-based retrieval.
- Multimodal information: synthesis of knowledge from multimodal resources.

Natural Language Processing

- Text: content-based retrieval and understanding.
- Speech: translation, understanding, generation with dialog.

c *Potential Military Benefits*

The contributions of the computer and information sciences to a well-equipped strategic force capable of decisive victory in conflicts in the information age will contribute in the following areas:

- Digitized battlefield
- Distributed C^2 and distributed interactive simulation
- Information processing
- Design and validation of software
- Adaptive, anticipative systems
- Intelligent systems and augmentation of human-centered systems
- Human–machine interface
- Battlefield management.

3 Physics

a *Strategy*

Physics provides the fundamental underpinnings for all other sciences and technologies. Thus, this area emphasizes the establishment of fundamental limits of technologies. The Physics Coordinating Group—together with representatives from participating RDECs, ARL/ARO directorates, and the Topographic Engineering Center—develop a strategy for investment. This group follows a 3-year plan for a broad-based research program that is organized into five subject areas: nanoscience, integrated sensory science, nonlinear optics and nonlinear dynamics, photonics, and image analysis. These programs support advanced technology development to provide increased signal processing and display, sensor protection and countermeasures, and target acquisition.

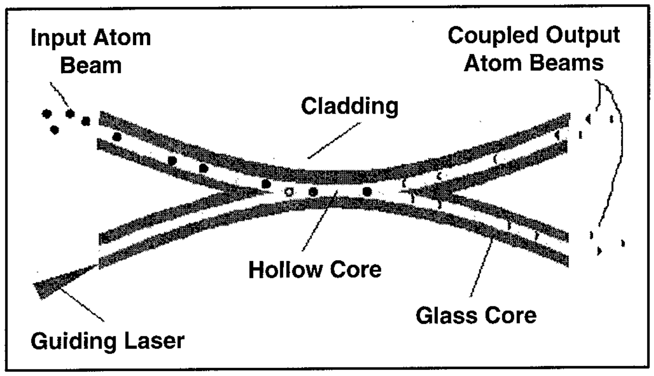
b *Major Research Areas*

Nanoscience. The objective of nanoscience is to develop the capability to manipulate atoms and molecules individually, to assemble small numbers of them into nanometer-size devices, and to exploit the unique physical mechanisms that operate in these devices. The program emphasizes self-assembly for rapid, low-cost, atomic-scale construction of these nanosystems.

Quantum coherence is another important area of interest in nanoscience. Recent advances in the theory of quantum computing have opened new possibilities for code-breaking technologies and other highly complex computational methods in a new physics-based program in quantum computing. Other areas of emphasis in this program are ultrafast phenomena, near-field microscopy, nanoscale manipulation, and quantum processes for noise reduction.

Integrated Sensory Science Integrated sensory science seeks to provide the Army with the ability to operate on the ground over relatively short ranges in conditions of poor visibility. Novel and improved radiation sources and detectors will continue to provide new capabilities for the Army, especially through the use of coherent optical and atomic systems and multispectral ima-

ging. Figure V–13 shows an atom-beam fiber coupler, which is used to guide and control atom beams. Other possible uses include controlled deposition of thin films and atom interferometry, which would allow highly precise measurements of atom beam positions. Control of physical signatures is now possible with the discovery of new materials and enhanced backscattering.



This device allows very precise control and measurement of atom-beam parameters.

FIGURE V–13. ATOM-BEAM FIBER COUPLER

Nonlinear Optics and Nonlinear Dynamics. The use of optical sensors and sources is analogous to the use of RF detectors and sources. In the future, technology based on nonlinear dynamic processes and phenomena is critical for the Objective Force with its requirements for lightweight, high-speed tactical capability. Research themes of current and future interest include nonlinear optical and other dynamic processes; tunable sources; materials with special reflective, absorptive, and polarization properties; and the ability to perform remote sensing of CB agents.

Photonics. Photonics seeks to develop optical subsystems for military applications such as information storage, displays, optical switching, signal processing, and optical interconnections of microelectronic systems. Research opportunities in photonic-band engineering include low observables, diffractive optics, hybrid signal processing, and unconventional imaging.

*Image Analysis.*The speed and complexity of modern warfare have led to the need for automatic target recognition (ATR). Although considerable advances have been made in ATR systems, a human must still make the final decision. ATR systems have been developed using heuristic and ad hoc techniques. The theoretical underpinnings of ATR still require further development. The objectives are to develop (1) a set of scientific metrics that quantify image content, complexity, and structured clutter, (2) a set of metrics to describe the performance of image recognition and classification techniques, and (3) a set of performance models that can predict performance and allow optimization of system design.

Other Research Areas. Humans use a variety of sensor modalities to gather information about their world. The Army needs to develop a science for the integration of a variety of sensors such as conventional imaging systems, sound detection devices, or chemical detection systems that will allow improved target recognition and discrimination.

c ***Potential Military Benefits***

These programs support advanced technology development to provide increased signal processing, signal display, sensor protection, and target acquisition. Novel and improved radiation sources and detectors will continue to provide new capabilities for the Army. In addition, atom optics are expected to provide new ultrasensitive detectors and clocks with applications that include global positioning and inertial navigation systems.

4 Chemistry

a *Strategy*

Army chemistry is planned and coordinated annually by the Army Chemistry Coordinating Group. This group comprises Army chemists from the ARL Directorates for Weapons and Materials Research and for Sensors and Electron Devices, Armaments RDEC (ARDEC), Edgewood Chemical Biological Center (ECBC), Natick Soldier Center (NSC), Army Communications–Electronics Command (CECOM), the U.S. Army Chemical Demilitarization and Remediation Activity, the Army Corps of Engineers–WES, the U.S. Military Academy, and ARO. The Army Chemistry Basic Research Program was briefed to DoD leadership at the Technology Area Review and Assessment (TARA) review in March 1998. Army chemists performed joint planning with the Navy and Air Force at the Tri-Service Reliance Meeting.

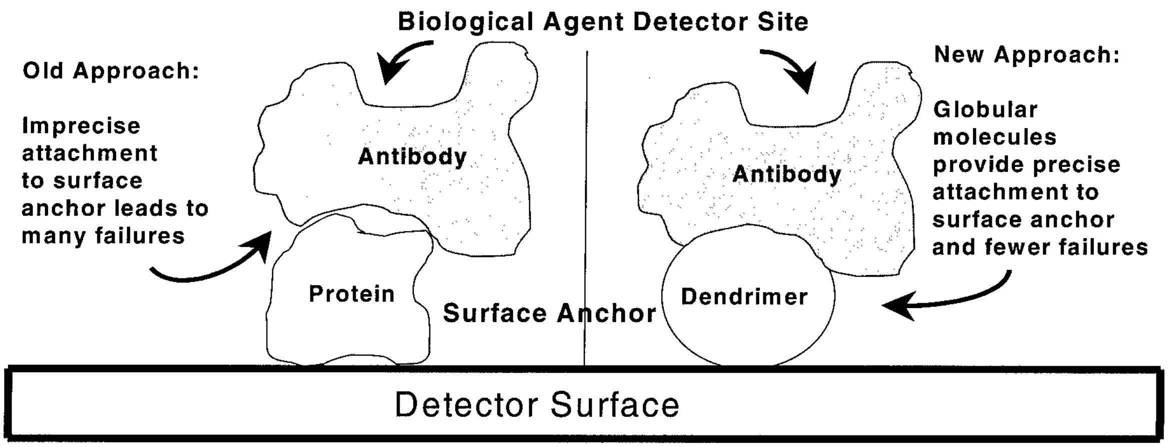
b *Major Research Areas*

Chemical Detection. Following the Army long-range strategy plan, research in chemistry continues to focus on programs for which the Army has lead responsibility: CB defense, advanced materials, combustion (including explosives and propellants), compact power sources, obsolete weapon demilitarization, installation restoration, and pollution prevention.

In accordance with the Tri-Service Reliance, chemistry is divided into the subareas of chemical synthesis and properties and chemical processes. Under chemical synthesis and properties, the Army has the lead for catalysts, reactive polymers, and dendrimers; the Army shares with the Navy and Air Force responsibility for functional polymers, energetic materials, power sources, nanostructures, sensors, lubricants, and elastomers. Under chemical processes, the Army has the lead for energetic materials ignition and combustion, CB decontamination and demilitarization, and diffusion in polymers. The Army shares responsibility for dynamics, corrosion, power sources, and sensors.

Army basic research on CB defense is carried out by ECBC, NSC, and ARL/ARO. This work supports the Army Soldier and Biological Chemical Command (SBCCOM) development programs on sensors, protection, and decontamination. Dendrimers are a new class of molecule that have a well defined globular shape. They are of interest to DoD because of their precise size and shape and also because they can be prepared in many different sizes to meet the needs of various applications. The first use of a dendrimer for biological agent detection is shown in Figure V–14. ARL/ARO investigators have developed the first combustion model for nerve gas simulants and model calculations for VX decontamination and have transitioned metal oxide powder decontaminants to ECBC.

Research on advanced materials is conducted by NSC and ARL. The ARL Materials Center of Excellence at Michigan Molecular Institute is developing syntheses of novel dendritic polymers; and of dendrimer and hyperbranched polymer-based organic and inorganic nanocomposites for CB sensors, electronics, bioprotection, membranes and coatings, flame suppression, fiber surface treatment, and resin additive applications. Working with ARL/ARO-supported investigators at Johns Hopkins University, ARL scientists are developing nondestructive characterization of gas or liquid permeation in polymer materials for CB protective material applications (e.g., disposable face mask, transparent armor and barrier materials, CB protection). ARL in-house programs include the multifunctional materials program—structure and property relations in



In the old approach to biological agent detection, a molecule with a biological agent detection site is attached to the detector surface using another complicated biological molecule. The attachment of two large, complicated molecules perturbs the detection site resulting in many failures. In the new approach, a dendrimer, which is a large globular molecule prepared in a variety of sizes, is chosen to match the detection molecule anchor site. By matching the two molecules, their attachment does not produce stress that affects the detection site; thus more attachments result in active sites.

FIGURE V–14. SYNTHESIS OF DESIGNED MOLECULES/DENDRIMERS

novel polymeric materials with special emphasis on materials for CB protection, soldier systems, and vehicle applications.

Power Sources. Research on power sources is performed by ARL and supports development at CECOM. ARL developed new high-voltage, high-conductivity electrolytes for high-energy capacitors and lithium-ion batteries. ARL/ARO, with support from DARPA, manages research on fuel cells, thermophotovoltaics, and microturbines.

Explosives and Propellants. Research on explosives and propellants is performed by ARL and ARDEC and supports development at Picatinny Arsenal and AMCOM. During the past year, Dr. Betsy Rice and Dr. Samuel Trevino of ARL received the Army R&D Achievement Award for their use of theoretical chemistry to determine a novel mechanism for detonation. Propellant burning rate models based on combustion data from ARL/ARO research are being transitioned into interior ballistic models for munitions design. Recent ARL accomplishments include new laser probes for propellant flames and theoretical calculations for propellant molecular dynamics. ARL/ARO investigators are clarifying the pathways for decomposition of energetic materials.

Energetic Materials. The ARDEC energetic materials program continues its focus on new, more energetic compounds from environmentally friendly syntheses. A University of Chicago–ARDEC collaboration led to the synthesis of methylheptanitrocubane and heptanitrocubane. ARDEC scientists demonstrated the feasibility of the Zeolite catalytic process for the preparation of O- and P-nitrotoluenes from toluene. This process does not yield any M-nitrotolune, which is the main culprit in the red water pollution associated with the production of TNT. ARDEC scientists isolated several enzymes that can affect the conversion of glycerine to nitroglycerine (NG) and vice versa. When optimized, this process would provide a safe, efficient commercial method for the production of NG as well as an excellent method for removal of NG from contaminated soils and other mediums.

Demilitarization/Environmental Remediation. Research on demilitarization, environmental remediation, pollution prevention, and chemical detection is performed by WES, ARL, and ECBC and supports development by the Corps of Engineers, AMC, and the program manager for chemical demilitarization. Basic research at WES enables understanding of chemical processes in the characterization, fate and transport, and treatment of contaminants in soil, sediment, and groundwater. WES scientists determined RDX, HMX, and abiotic TNT chemical transformation in soils. ARL accomplishments include discoveries on halon replacement compounds, development of state-of-the-art chemical sensor technology for the detection of toxic combustion byproducts, determination of the environmental fate and effects of halon substitutes, and use of plasmas to remove chemical-agent-resistant coatings from equipment. Important work continues at ARL on supercritical fluid extraction for recycling and reuse of energetic materials.

c *Potential Military Benefits*

New materials will enhance soldier protection against ballistic and CB threats and provide stronger, lighter structures for vehicles. Compact electric power will support the soldier for longer missions with less to carry. New explosives and propellants will enhance effectiveness and reliability and reduce vulnerability. New sensors will protect the soldier from explosive and CB threats. Weapon demilitarization and base cleanup research will reduce costs to manage Army inventory and to clean up the environment.

5 Materials Science

a *Strategy*

The overall objective of the materials science program is the elucidation of the fundamental relationships that link the composition, microstructure, defect structure, processing, and properties of materials. The work, although basic in nature, is focused on those materials, material processes, and properties that improve the performance, increase the reliability, or reduce the cost of Army systems.

Research priorities are defined in the *Material Science Investment Strategy Plan,* which is prepared by the Army Materials Coordinating Group. This group is composed of scientists from ARL/ARO, participating RDECs, ARL directorates, and TRADOC. The plan outlines a strong multidisciplinary program in materials science that emphasizes research in five broad areas: manufacturing and processing of structural materials for Army vehicles and armaments, materials for armor and antiarmor, processing of functional (electronic, magnetic, and optical) materials, engineering of material surfaces, and nondestructive characterization of components for in-service life assessment.

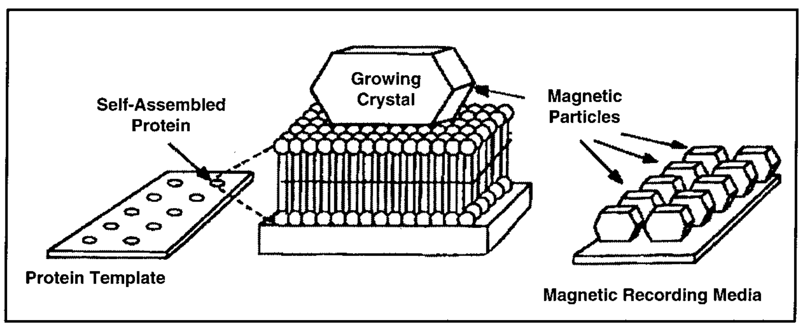
The Rodman Materials Research Laboratory—a major, new Army research center at Aberdeen Proving Ground—has begun operations. The staff includes materials scientists and synthetic, physical, polymer, analytical, and theoretical chemists from the ARL Weapons Research and Materials Directorate. This modern experimental facility will enhance productive interaction among Army scientists working on a wide range of materiel problems.

b *Major Research Areas*

Microscopic Versus Macroscopic Domain. The materials field is highly interdisciplinary, encompassing such diverse specialties as physical metallurgy, solid-state physics, chemistry, biology,

penetration mechanics, surface science, and materials analysis. On the submicroscopic level, research is concerned with the manipulation of atoms and molecules and with the interactive forces that bind them. There is a strong emphasis on such topics as electronic and atomic structure, bonding character, and the many interactions of radiation and particles with condensed matter. At the microscopic level, the field is concerned with the effects of chemistry, microstructure, and phase transitions on the structural and functional properties of materials. At the macroscopic level, research is concerned with the continuum behavior of materials and composites. There are expanding opportunities for advancing the science of materials through continued integration and understanding of the interrelationships between the microscopic and macroscopic domains. This is reflected by the increasing integration of material modeling and numerical simulation into materials science.

Material Synthesis and Self-Assembly. New generations of materials with vastly improved properties are currently under development. Technology has now progressed to the point where it is possible to observe and manipulate materials at the atomic scale. This affords the opportunity to begin introducing much greater robustness into the design of materials and new possibilities for enhancing their performance. A growing interest by the Army is the design and fabrication of materials at submicron dimensions. New approaches to material synthesis based on self-assembly of surfactants or proteins on surfaces, microcontact printing and micromolding, and flexible manufacturing approaches are under development. Examples of materials prepared using self-assembled proteins as a template for subsequent magnetic particle growth are shown in Figure V–15.



Magnetic recording media is prepared using self-assembled proteins as a template for subsequent magnetic particle growth.

FIGURE V–15. MATERIAL SYNTHESIS

Smart Materials. This research is laying the foundation for the development of new generations of materials that will bear scant resemblance to the rudimentary materials technology that the Army depends on today. For example, a new class of "smart" materials is under development that will be able to sense its environment and significantly alter its properties to adapt to changing conditions. Likewise, molecular recognition and self-assembly techniques, which mimic natural processes, are being investigated as a synthesis route to new classes of multifunctional supramolecular systems.

c *Potential Military Benefits*

Materials science research supports the entire Army materiel acquisition effort by ensuring that materials will exist that fully satisfy future mission requirements for improved firepower, mobility, armaments, communications, personnel protection, and logistics support. The emphasis is on developing new materials and processes that will significantly enhance materiel performance and reliability and reduce overall system costs. Major areas of impact include Army needs for individual soldier protection, armor/antiarmor, air and ground vehicles, bridging, shelters, communications, target acquisition, data processing, and power generation.

Figure V–15 is an example of how biomimetic processing could be used to produce an improved magnetic recording medium. New levels of control over the size and placement of the magnetic particles could be attained by using protein self-assembly as a template for subsequent particle deposition.

6 Electronics Research

a *Strategy*

Electronics is an enabling technology for all future Army systems for the digitized battlefield of the Objective Force. In particular, electronics research provides the seminal knowledge for exploring new systems and enhanced capabilities for radar and radiometry, communications, C^2, fire control, electronic warfare, navigation, weapon guidance and seekers, and night vision devices. Army electronics research focuses on the generation of technology that will enable systems to function within the constraints imposed by the need for operation on small platforms—the soldier, truck, armored vehicle, and helicopter—that are used in highly mobile land warfare. To achieve this goal and to maintain technological superiority, emphasis is placed on the investigation of a spectrum of near- to far-term technologies. The research is reviewed, shared, transitioned, and transferred through the Reliance Electronics Planning Group process, the technology area plans, TARA, and the Electronics Coordinating Group (ECOG) activities.

b *Major Research Areas*

Army electronics research emphasizes three broad areas.

Solid-State and Optical Electronics. Solid-state and optical electronics research in the near term includes advanced semiconductor devices supporting Objective Force applications, quasi-optical techniques for advanced MMW and sub-MMW systems, low-power electronics, advanced IR sensor concepts, short-wavelength lasers, and related materials issues. In the long term, electronics research must provide for novel, robust, reliable multifunctional ultrafast and ultradense electronics, and optoelectronic components and architectures. High-resolution, high-sensitivity, multicolor IR imaging arrays are required for target acquisition, recognition, and identification. Research thrusts include advanced materials, novel device structures, and appropriate system architectures. Ultrafast signal processing computing will require advances in light emitters. New system architectures are needed for increased data storage and efficient optical processing. As shown in Figure V–16, a key element in solid-state and optical electronics research is atomic-level feature control to provide devices that will meet the Army's future technology needs in device integration and information capacity.

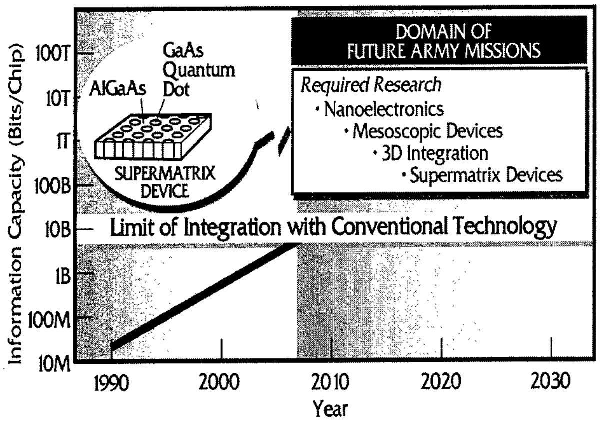


FIGURE V–16. ADVANCEMENTS IN DEVICE INTEGRATION AND INFORMATION CAPACITY THROUGH SOLID-STATE AND OPTICAL ELECTRONICS RESEARCH

Information Electronics. Information electronics research is driven by the profound growth of battlefield information sources and the complexity and need to process and communicate that information in near real time for the digital battlefield concepts. Objective Force operational concepts call for a highly mobile force, the success of which depends on (1) reliable voice, data, and video communications on the move, and (2) information with the minimum latency and varying quality of service requirements to ensure quick decisions and synchronous operations. Research is conducted in network management, network protocols and architectures, message routing including flow and congestion control, forwarding algorithms, advanced switching technology and interfacing, and integration of heterogeneous networks. Methods for the design of large, distributed, mobile spread-spectrum packet radio network architectures, protocols, routing, and control are investigated. The use of adaptive-array antennas in networks to provide spatial reuse of the limited spectrum, increase network throughput capability, increase interference and jamming resistance, and lower transmit power requirements is investigated. Information fusion includes both sensor and data fusion techniques. It encompasses a number of scientific disciplines, including signal, image, and speech processing; decision theory; distributed heterogeneous databases; and intelligent systems.

Electromagnetics. Electromagnetics research focuses on issues unique to Army needs such as circuit integration, antennas, and propagation that will enable Army exploitation of the terahertz, MMW, and high-frequency microwave portion of the spectrum for communications and radar and seeker systems for the digitized battlefield. Power-combining techniques such as quasi-optics are critical in enabling moderate- or high-power MMW systems with the advantages of solid-state electronics. Optical control of microwave and MMW circuits provides the opportunity for low-weight, low-cost control of antenna arrays.

c *Potential Military Benefits*

A key element in electronics research is atomic-level feature control to provide devices that will meet the Army's future technology needs in device integration and information capacity (Figure V–16). Enhanced performance and functionality of future electronics will lead to faster, more portable, and more reliable systems for target identification; intelligent systems for better command and control of fire support missions; miniaturized computers and displays with improved processing capability; data fusion of multidomain, compact, smart sensor suites; enhanced timing and location systems for autonomous weapons; optimized man–machine interface; ultrafast information processing in extremely small, massively parallel processors; high-data-rate communications; and ultra-small integrated multifunctional sensors for the soldier. Real-time signal processing is critical to communications, adaptive-array antennas, and signal intercept as well as image analysis, target acquisition, and information fusion. Signal and information processing is used in the implementation of image, radar, speech, antenna, and communication processing systems for applications in target detection, identification, and tracking; guidance and control; fire control; and communication. Research in fast, high-resolution,

null- and beam-steering and compact adaptive antennas will provide low-signature communication and improved signal intercept capability.

7 Mechanical Sciences

a *Strategy*

The Army's reliance on mobile systems to perform its mission requires a major research effort in the mechanical sciences to provide the technology base that will enable the development of vehicles and their armaments with significantly advanced capabilities to meet the requirements of the Objective Force. The Army Mechanics Coordinating Group (MECOG) has developed a strategy for focusing the Army's future research programs in the mechanical sciences on the most opportune and important areas. The strategy takes advantage of the reliance process with the Navy and Air Force and is peer-reviewed at the annual DDR&E TARA.

b *Major Research Areas*

The MECOG developed the appropriate research thrusts and assigned priorities, while regularly coordinating in-house and extramural research efforts, in four major fields of the mechanical sciences that are critical to Army interests.

Structures and Dynamics. The research topic areas in this field are structural dynamics and simulation, air vehicle dynamics, and weapon system and land vehicle dynamics. The higher priority research thrusts in structural dynamics and simulation are smart structures, structural dynamics, structural damping, active structural control, structural health modeling, and inflatable structures. Air vehicle dynamics focuses on integrated rotorcraft aeromechanics analysis, smart structures and active control of rotary-wing systems, projectile aeroelasticity, and parachute aeromechanics. Multidisciplinary research on advanced active control of coupled rotorcraft vibration and aeroacoustics offers a significant potential reduction in rotorcraft vibration and acoustic radiation for the Objective Force (Figure V–17). In the area of weapon system and land vehicle dynamics, the research thrusts include weapon system precision pointing, multibody dynamics, and vehicle simulation.

Solid Mechanics. The research topic areas in this field are deformation and failure, impact and penetration, automated computational optimization for design of systems, scaling laws, and mechanics of heterogeneous structures. Research topics under deformation and failure include constitutive models, bridging scales, damage and failure processes, and computational algorithms for large-deformation transient response. Impact and penetration mechanics includes research in 3D simulation, advanced diagnostics, and innovative structures. (Innovative structures includes a special basic research program on smart resilient structures involving novel material concepts, material behavior, responsive mechanisms, and analytical tools that provide the fundamental underpinnings for a technology-to-engineering development program for responsive armor concepts needed for the Objective Force.) Automated computational optimization for the design of systems focuses on system optimization and evolutionary algorithms. Research in scaling laws involves size effects, processing, and stochastic effects. Mechanics of heterogeneous structures focuses on multiscale mechanisms, wave propagation and dispersion, and reliability.

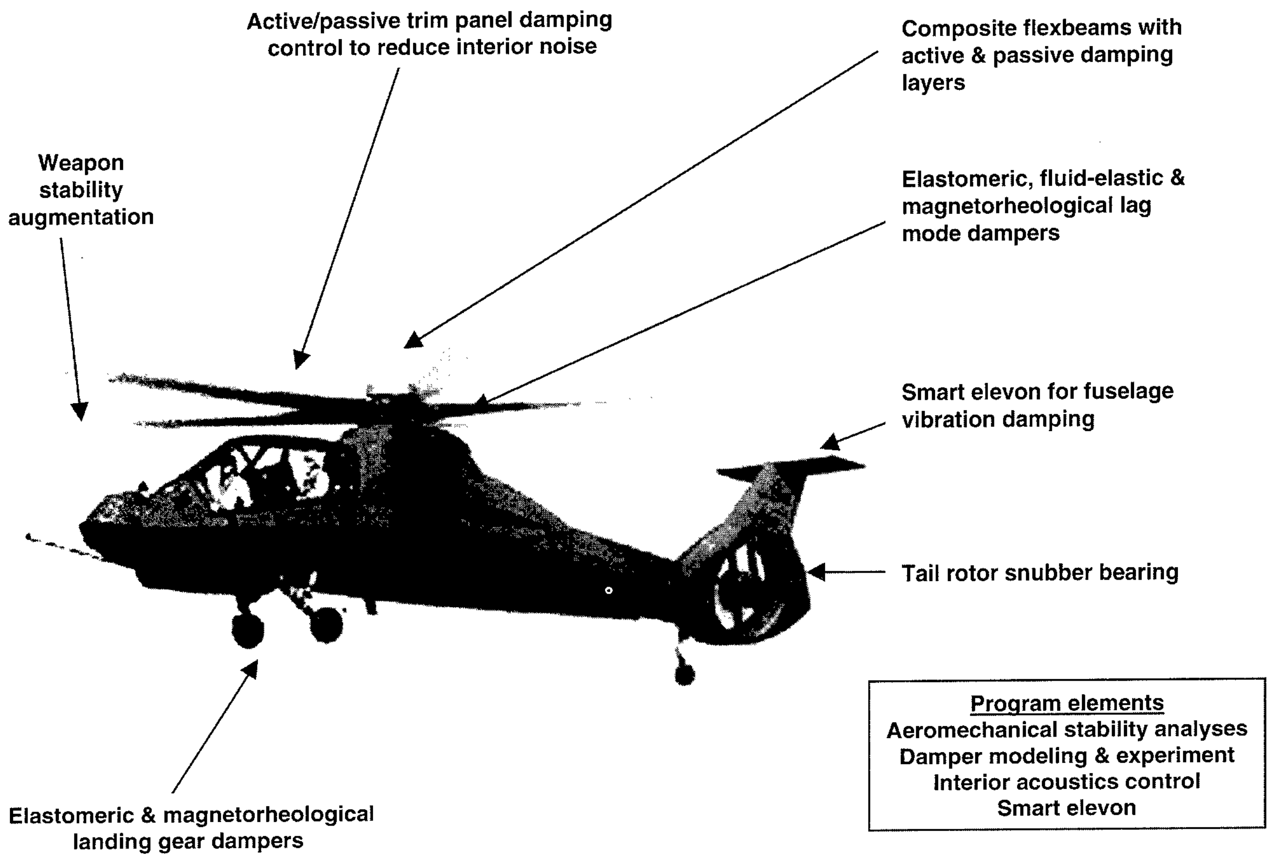


FIGURE V–17. PASSIVE/ACTIVE DAMPING CONTROL FOR ROTORCRAFT SYSTEMS

Fluid Dynamics. The research topic areas in this field are rotorcraft wakes, unsteady aerodynamics, rotorcraft aeroacoustics, and thermal science of micro- and mesoscale devices. The higher priority research thrusts in unsteady aerodynamics are dynamic stall unsteady separation, maneuvering missiles and projectiles, and parachute opening. Micro-/mesoscale device research focuses on support of the development of a wide variety of innovative compact systems, including microturbine power generators, air and water purifiers, compact cooling systems, and miniature unmanned aerial vehicles. Successful development of these systems will require research into the thermodynamics, heat transfer, and fluid dynamics of these miniature devices, as well as the multidisciplinary integration of these thermal science disciplines with chemistry, structural dynamics, and materials sciences.

Combustion and Propulsion. The research topic areas in this field are small gas turbine engine propulsion technology, reciprocating engine technology, solid gun propulsion, liquid gun propulsion, and novel gun propulsion. The higher priority research thrusts in small gas turbine engine propulsion are critical combustion processes, enhanced optimization, and integration of miniature sensors and active controls. Reciprocating engine technology focuses on ultra-low heat rejection environments, enhanced air utilization, and cold-start phenomena. Areas of focus for solid gun propulsion include ignition and combustion dynamics and high-performance solid-propellant charge concepts; for liquid gun propulsion, they include atomization and spray combustion, ignition, and combustion mechanics as well as instability, hazards, and vulnerabil-

ity; and for novel gun propulsion, they include ignition and combustion processes and novel hypervelocity launch concepts.

c *Potential Military Benefits*

Research supported by mechanical sciences provides the necessary tools to enable prediction, design, simulation, and assessment of future Army air and ground vehicles, including their powerplants and armament systems, which would result in increased performance, reliability, sustainment, and mobility. In particular, Army research can be expected to provide advanced, higher performance rotorcraft and vehicle gas turbine engines, stable weapon system platforms, accurate supply and weapon-on-target delivery capabilities, resilient structures for heavy and light fighting vehicles, vehicle structural reliability and survivability, more energetic and reliable gun propellants, advanced EM gun propulsion systems, high-power-density diesel engines, weapon failure analysis and prediction, and multibody vehicle simulation capabilities. Mechanical sciences have a significant impact on seven mission and technology thrust areas: Aviation; Ground Combat and Tactical Systems; Weapons; Soldier and Personnel Technologies; Engineering, Combat Construction, Mobility, and Countermobility; Logistics; and Materials, Material Processes, and Structures.

8 Atmospheric Sciences

a *Strategy*

The atmospheric environment impacts every aspect of Army operations. Prior quantitative knowledge of present and future environmental conditions, consequences, and limitations is essential for intelligence preparation of the battlefield, for developing improved weapon systems, for using weather conditions as a force multiplier, and for enhancing the Army's all-weather capability.

Present and future research focuses principally on the atmospheric boundary layer—where the Army operates—at higher time and space resolution than ever before. Basic research in the atmospheric sciences is multidisciplinary, using understanding of electromagnetic and acoustic propagation in the atmosphere, fluid dynamics and turbulence, radiative energy transfer, and thermodynamics of mixed phases of water to assess the natural and induced environment over the land. Ultimately, the science must lead to viable tools and information to the Army user community.

Under Project Reliance, the Army has the primary responsibility for scientific issues concerning the atmospheric boundary layer over the land. Furthermore, the Army is responsible for providing environmental data for its own needs at battlefield and smaller scales. The Atmospheric Sciences portion of the Army's Environmental Sciences Coordinating Group (ESCOG) meets triennially to develop a strategic plan for focusing research by identifying and assigning priorities to promising basic research thrusts. The in-house and extramural research progress is regularly peer-reviewed and briefed in various Army and DoD forums.

b *Major Research Areas*

ESCOG recently identified 10 primary areas of research thrusts in atmospheric sciences for the coming 5 years. These thrusts are being coordinated with the principal thrusts of the Objective Force. The 10 areas of research fall in three principal research sectors vital to the Army mission.

Atmospheric Effects on Sensors and Systems. Chemical and biological defense has the Army's highest priority. Detection, classification, and identification of airborne aerosols and gases are essential to that defense. Standoff capability relies on passive or active sensing of the atmospheric content and the effects of the material and the atmosphere on the propagation from source to detector. Thus, both the atmospheric path and the species must be well understood.

Atmospheric turbulence on very small scales in the lower atmosphere can severely impact the performance of image-forming optical and infrared systems, as well as acoustical arrays used for determining source bearings, by creating strong local gradients of temperature and moisture that locally distort the index of refraction of the atmosphere. Modern, high-resolution imaging systems are often turbulence limited rather than diffraction limited, impairing long-range, high-resolution target acquisition, recognition, and identification. A fundamental understanding of the intermittent, inhomogeneous, and anisotropic nature of atmospheric turbulence is essential to understand and mitigate these limitations. Careful observations and numerical simulation of atmospheric turbulence can improve understanding of realistic atmospheric turbulence and its effects on electromagnetic and acoustic system performance at small scales of time and space.

Heterogeneity of natural environments in the atmospheric fields, soil moisture and composition, and ground cover significantly affects the signals received by electromagnetic and acoustic sensors. These features vary globally and often at small scales with sharp discontinuities. Scattering of EM and acoustic waves from all types of surfaces is important to many systems or techniques used by the Army to accomplish its mission.

Characterization of the Atmospheric Boundary Layer at High Resolution. The atmospheric boundary layer over land continually evolves in response to daytime heating and nocturnal cooling over inhomogeneous terrain. This produces significantly different conditions over short temporal and spatial scales that affect the Army's ability to assess and predict current and future conditions of the battlefield. Advanced models and simulations of these processes are needed to provide quantitative and qualitative information on battlefield conditions at small scales. In particular, the stable boundary layer and the transitions to and from the convective daytime conditions are poorly understood. A combination of measurement of evolving boundary layer processes, development of theory and physically consistent parameterization of very small-scale processes, and engagement scale modeling of atmospheric processes is needed to meet Army needs. Accurate methods for assessing the transport and dispersion of hazardous agents and obscurants, especially to quantify their mean and fluctuating concentrations in all stability and terrain conditions, continue to receive extremely high priority.

Development and demonstration of a capability for remote sensing of the atmospheric boundary layer of wind velocity, temperature, and moisture in four dimensions at scales of time and space of interest to the Army remain a high priority. The sensed data should provide quantitative information on the inhomogeneity of the atmosphere as a propagation medium and as a dispersion medium for natural and induced aerosols (Figure V–18).

Management of Atmospheric Information. Providing useful information on atmospheric effects to the soldier and decisionmaker is the focal point of the Army's atmospheric sciences effort. Moreover, the information must be in a form that is readily understood and meets the user's needs while being physically based. Since all forecasts and observations have some error, a capability to objectively assess the uncertainties of the basic data and the effects of using the data in decisions is needed. Atmospheric information comes from direct measurement (e.g., temperature, pressure) and from indirect observations (e.g., multispectral satellite-measured

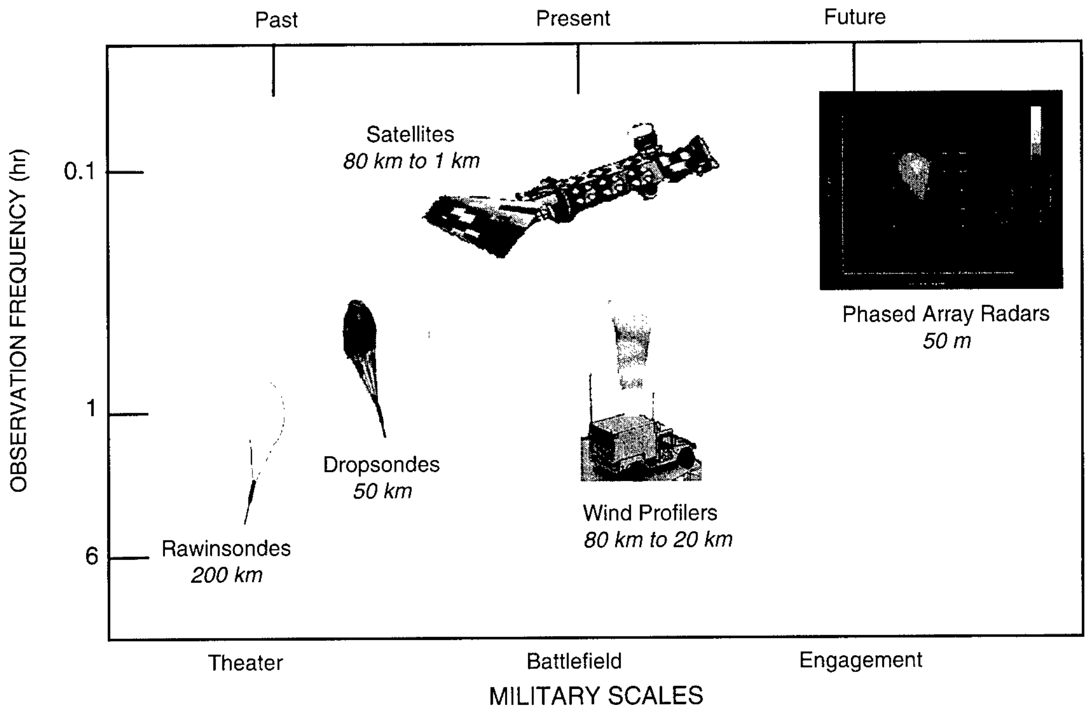


FIGURE V–18. SENSING ATMOSPHERIC PROPERTIES

radiances of clouds or ground or atmospheric effects on transmission). Assimilation of both data types into a forecast model or into a current battlefield visualization is essential in maintaining battlefield awareness at all echelons. To enable effective information management, innovative high-performance computational methods that represent the detailed atmospheric flows in real terrain and in all stabilities and that assimilate and display information (including the wave propagation codes in turbulence) are high priorities.

c *Potential Military Benefits*

Atmospheric boundary layer research serves all services through improved characterization of rapidly changing boundary layer processes over land in weather prediction models. It specifically supports multiple functions of the Army's Integrated Meteorological System (IMETS) in intelligence preparation of the battlefield, in battlefield visualization, and in situational awareness. Research in turbulent structures of the boundary layer leads to a significantly improved dispersion model applicable to open detonation and open burning of munitions; improved prediction of transport and diffusion of NBC materials on a small scale of time and space over varied terrain shapes and ground covers and at all times of day; modeling effectiveness of smoke and other obscurants in realistic scenarios; and assessment of the atmosphere as a propagating medium for electromagnetic and acoustic energy.

Remote sensing of wind fields will also enable detection of hazardous and variable winds in aircraft landing zones, in paradrop zones, above urban areas, and in accidental release of hazardous gases or aerosols. Active and passive remote sensing research is essential to detection of objects in snow or on the ground, to modeling, and to rapid detection of natural and man-made features, including camouflage.

9 Terrestrial Sciences

a *Strategy*

The Army operates upon the Earth's surface and its ephemeral natural surface covers. The broad range of terrestrial features and environmental conditions that may confront the Army around the world can constitute either a formidable barrier or a significant advantage. To be successful, the Army must be maintained in a state of readiness, have the maximum possible mobility when deployed, and be able to operate and perform missions efficiently at full capability throughout the world in operational theaters that may range from equatorial to polar latitudes, encompass terrain from coastal lowland areas to deserts and mountains, and comprise both natural and urban environments. The key determinants to success are (1) a knowledge of terrain characteristics and behavior and (2) the ability to incorporate that knowledge into military doctrine, system development, training, planning, and operations.

Basic research in terrestrial sciences is concerned with the impact of surface and near-surface environment on Army activities, and is directed at those particular elements that may have significant bearing on readiness and the planning, logistics, and execution of military campaigns. There is a particular need to better understand, model and simulate, and predict those conditions and environments that are most dynamic or restrictive to system performance or military operations.

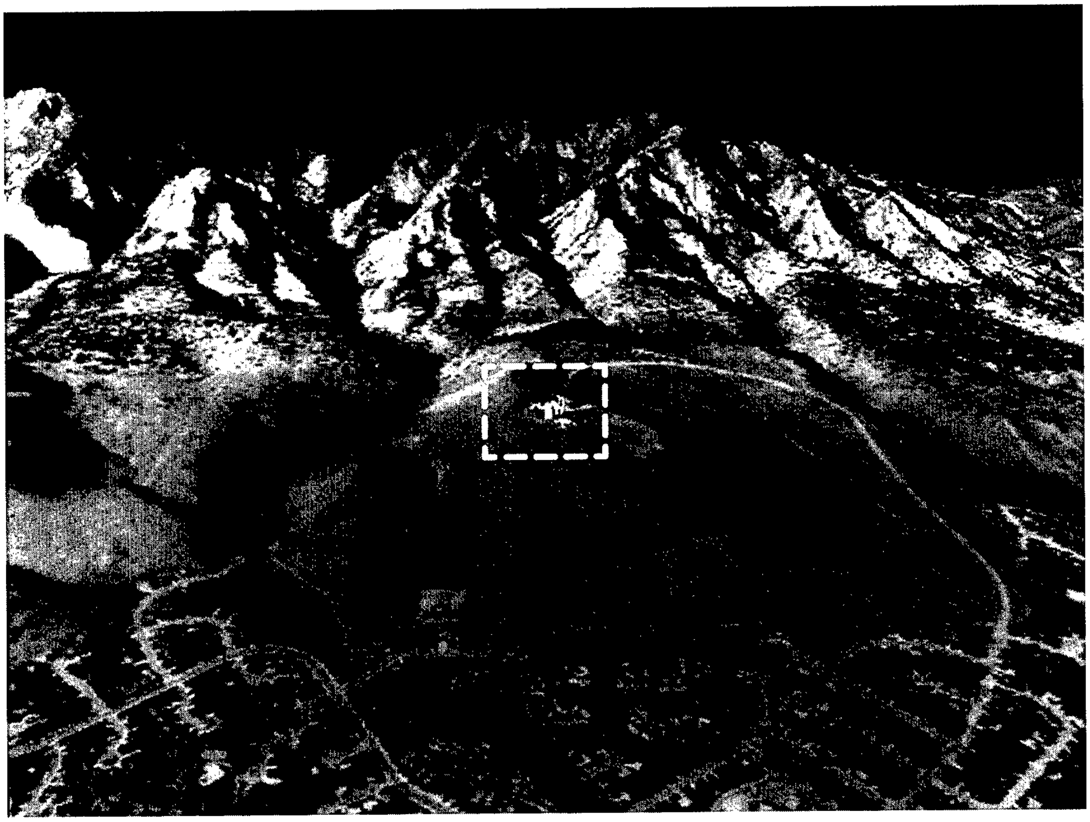
The vision, long-term strategy, and research priorities for basic terrestrial sciences research by the Army are defined in ESCOG's *Environmental Sciences Strategy Plan.* The plan outlines a strong multidisciplinary program in the terrestrial sciences.

b *Major Research Areas*

Research emphasized is in three broad areas: terrain properties and characterization, terrestrial processes and landscape dynamics, and terrestrial system modeling and model integration.

Terrain Properties and Characterization. Terrain affects all aspects of Army operations, including mission planning, system performance, unit mobility and operational effectiveness, and training readiness. At present, the Army cannot rapidly and efficiently perform the terrain analysis that is required before vehicles and weapons can be deployed. Characterization of the surface geometry and features of complex terrain (as illustrated in Figure V–19) is needed to enhance planning and tactical decisionmaking and to tailor equipment to the challenges of the natural environment. Both fundamental data on the distribution and character of natural and man-made features and information about the dynamic condition of the terrain are required for rapid mapping. Such information must be coupled to models that quantify dominant physical processes to allow temporal forecasts of the conditions to be faced by soldiers and materiel.

Terrestrial Processes and Landscape Dynamics. Enhanced understanding and numerical description of terrestrial processes affecting Army operations are the focus of this research area. Improved measurements and theoretical treatments are needed to treat the complex, often nonlinear dynamics governing these processes, which often operate over a wide range of discontinuous scales of time and space that make them extremely difficult to characterize and quantify. Of particular research interest are those operational environments (i.e., cold region, desert, tropic, coastal, mountains, and urban) that are most restrictive to the Army. Geomorphic activity exerts a driving feedback on the hydrologic cycle. These fluid–terrain interactions and feedbacks are highly nonlinear and operate over a very broad range of spatial and temporal scales.



3D view of the Boulder, Colorado, area with the National Center for Atmospheric Research headquarters buildings in the center of the field. This photographic image was draped over a digital elevation terrain model using a digital sensor projector (VESPER: Visualization Environment Supporting Photogrammetry and Exploitation Research), which projects image pixels from the sensor plane into a 3D scene to create a precise scene rendering. This technology is important for real-time battlespace visualization, mission planning and computer simulations, smart weapons targeting and in-flight guidance, mobility planning, and numerous other DoD applications.

FIGURE V–19. TERRAIN FEATURES

Critical to developing an engineering-scale understanding of the properties and behavior of surface environments is a fundamental knowledge about the processes that operate on surficial materials at a variety of scales. Field observation, laboratory experimentation, and computational modeling must be integrated to solve well-formulated problems. Predictive geotechnical models, based on well-characterized constitutive relationships, are required to identify controlling processes and parameters across a spectrum of scales.

Terrestrial System Modeling and Model Integration. A major objective of the effort to characterize the natural environment and study surficial processes is to develop or enhance integrated system models and simulators. The information and products arising from research will result in improved model input parameters or enhanced numerical methods, algorithms, and simulation capabilities. The Army must continually develop new features for existing numerical models and, in some instances, new environmental model systems. Two areas of particular interest are vehicle–terrain interaction and sustainable land use. The Army has an acute need to understand the influence of soil properties and behavior on mobility in the context of providing real-time trafficability assessments and mobility predictions for commanders; and to permit the improved design, procurement, and evaluation of new vehicles. It is also necessary to understand the interrelated impacts of land-based military training and testing on terrain, hydrologic

networks, geomorphic response quality, and ecosystems; and to develop integrated models that can be applied to military land management and natural resources conservation.

c *Potential Military Benefits*

Army doctrine has long dictated that commanders know the terrain. Hence, commanders at all levels within the Army need to be familiar with the environment and understand how environmental factors and conditions can impact their operations and the operations of their adversary. Coupled with weather, the resulting variety and dynamics of the terrain and surface environment affect all aspects of the Army mission. The concept of the digital battlefield requires detailed and sophisticated information about terrain features and dynamic environmental conditions that can be provided to the appropriate operational level in real time. The Army will rely on enhanced battlefield awareness and precise timing to conduct well-coordinated massing of forces to quickly overwhelm enemy forces with minimal loss of manpower and materiel. This vision relies on three force-multiplying capabilities: (1) the ability to use realistic, dynamic terrain for interactive training, mission planning, and rehearsal; (2) the ability to effectively model vehicle–terrain interaction, assess mobility, and predict trafficability under current environmental and battlefield conditions; and (3) a full situational awareness on the battlefield that will enhance a commander's ability to visualize a battlefield at multiple resolutions and execute combat operations using an efficient decisionmaking cycle much more rapidly and effectively than an adversary. In addition, dynamic 3D terrain models will be the enabling foundation for interservice, intelligent autonomous weapon systems.

10 Biomedical Research

a *Strategy*

Military biomedical research is concerned with sustaining warfighter capabilities in the face of extraordinary battle and nonbattle threats through the preservation of combatants' health and the optimization of mission capabilities. Basic biomedical research focuses on health threats of military importance, supporting the DoD mission to provide health support and services to U.S. armed forces. The Army medical research mission is unique among other large national and international medical research programs, as well as those of the private sector. The National Institutes of Health, for example, focuses primarily on diseases affecting the U.S. civilian population. Similarly, private industry is driven by civilian disease demographics and profit incentives. In contrast, military research is oriented to the unique health threats posed by weapons of mass destruction and by the unusual geographic, environmental, and operational environments in which the Army must function. Recognizing the large investment in basic biomedical sciences within the civilian sector, the Army leverages emerging nonmilitary research efforts by positioning its biomedical basic research programs to exploit, rather than sustain, the medical technology base. A variety of cooperative agreements with industry and other government agencies play an integral role in this strategy. Intensive quality-control efforts and streamlined program practices have accelerated research protocol development to maximize technology transition to support the force. Joint coordination and cooperation within and among various functional areas, while preventing duplication of effort, are accomplished through the Armed Services Biomedical Research Evaluation and Management (ASBREM) Committee and its subordinate joint technology coordinating groups.

b *Major Research Areas*

Medical basic research programs ensure that cutting-edge scientific advances are fully and effectively integrated into the resolution of military-unique challenges. The four functional areas of medical capability most critical to maintaining effective medical technological superiority are infectious diseases of military importance, medical CB defense, military operational medicine, and combat casualty care. This functionally aligned research investment mitigates the effects of unforeseen technological events that could overwhelm medical countermeasures to threats to the health and performance of the armed forces.

Infectious Diseases of Military Importance. Basic research in infectious diseases of military importance provides an understanding of disease organisms, disease processes, and human responses to disease necessary to identify novel immunological and pharmacological approaches to prevention, diagnosis, control, and treatment of diseases affecting readiness or deployment. Basic research also develops fundamental research tools, techniques, and materials to facilitate vaccine and drug discovery. Molecular biology will facilitate rational design and discovery of vaccines and prophylactic drugs to prevent illness, new vaccine delivery systems, and rapid diagnostic tests based on genetic probes. Special emphasis will be placed on sequencing the genomes of disease-causing organisms, starting with malaria; characterizing interactions between pathogenic organisms and their hosts using animal systems; and researching novel vaccine strategies that offer potential for addressing multiple-threat agents. Also important in basic research is the tracking of new diseases through epidemiologic case studies and interfacing with the Global Surveillance and Response System. Together, these capabilities allow timely identification of new infectious disease threats to military operations.

Medical CB Defense. Medical CB defense focuses on military threat agents of biological or chemical origin. Basic research in medical biological defense focuses on biochemical, immunological, or microbiological characterization of biological warfare threat agents and toxins; understanding of disease processes caused by them; identification of the mechanisms of protective immunity; and discovery and characterization of suitable model systems. Basic research in medical chemical defense provides an understanding of the pathophysiology of threat agents and elucidates threat agent mechanisms of toxicity so that rational countermeasure strategies directed against those threats can be designed. Research is ongoing to identify methods of stimulating host immunologic protection against a broad spectrum of biological warfare agents. Also under investigation are medical diagnostics based on DNA analysis, bioengineered vaccines with multiple immunogenic properties, and approaches to block the actions of biological threat agents on target receptor sites. Reduction of incapacitating effects and prevention of death caused by biological and chemical warfare agents remain high priorities in both research areas, drawing on advances in such areas as immunology and molecular biology to develop more effective and less debilitating medical countermeasures.

Military Operational Medicine. Basic research in military operational medicine provides an understanding of the pathophysiology of environmental and occupational threats affecting soldier health and performance. These threats include extreme climatic or terrestrial environments, the rigors of military operations themselves (e.g., continuous operations, deployment stress), and system-associated health hazards (e.g., electromagnetic or nonionizing radiation, noise, vibration, blasts, toxic chemical byproducts). Most products in this functional area are informational and serve as guidelines for materiel and combat developers (e.g., hazardous noise and vibration standards, work–rest cycles, hydration and dehydration guidelines); however, advances in neurosciences and molecular biology may lead to medical products that reduce

susceptibility to fatigue or injury. The pace of medical research must exceed future weapon system development of resolution of system hazards. The research will be incorporated into emerging policy and doctrinal publications. Research will include the analysis of changes in visual performance in response to operational stressors to improve the design of displays and operator selection criteria. Additionally, it will include investigation of biomarkers that can indicate exposure to hazardous (nonthreat) chemicals, and identification of metabolic regulators (drugs and supplements) and other strategies that may reduce the incidence and severity of altitude-related injuries.

Combat Casualty Care. Basic research in combat casualty care focuses on the biological responses to traumatic conditions such as hemorrhage, low blood flow, and poor oxygen delivery. These studies develop a trauma database to identify potential diagnostic and prognostic indicators. They also contribute to the development of suitable models of injury that can be used to evaluate drugs, biologicals, devices, and medical techniques that may be beneficial in triage, immediate treatment, resuscitative surgery, or critical care during sustained evacuation. Emphasis is also placed on developing signal-processing techniques and models of physiological response that can be integrated into intelligent life-support systems.

c *Potential Military Benefits*

The above basic research programs provide the foundation for medical technological superiority in support of the National Military Strategy. Figure V–20 illustrates the impact that biomedical research can have on warfighting capability. In peace, medical technological superiority is a critical element of deterrence that bolsters the confidence of our coalition partners, and is the foundation of soldier readiness. In crisis, medical technological superiority ensures that threats to the health of the force do not constrain available military options of the National Command Authorities. Military health care delivery also enables superior performance across the spectrum of military operations. Military medical research programs are directly responsible for the

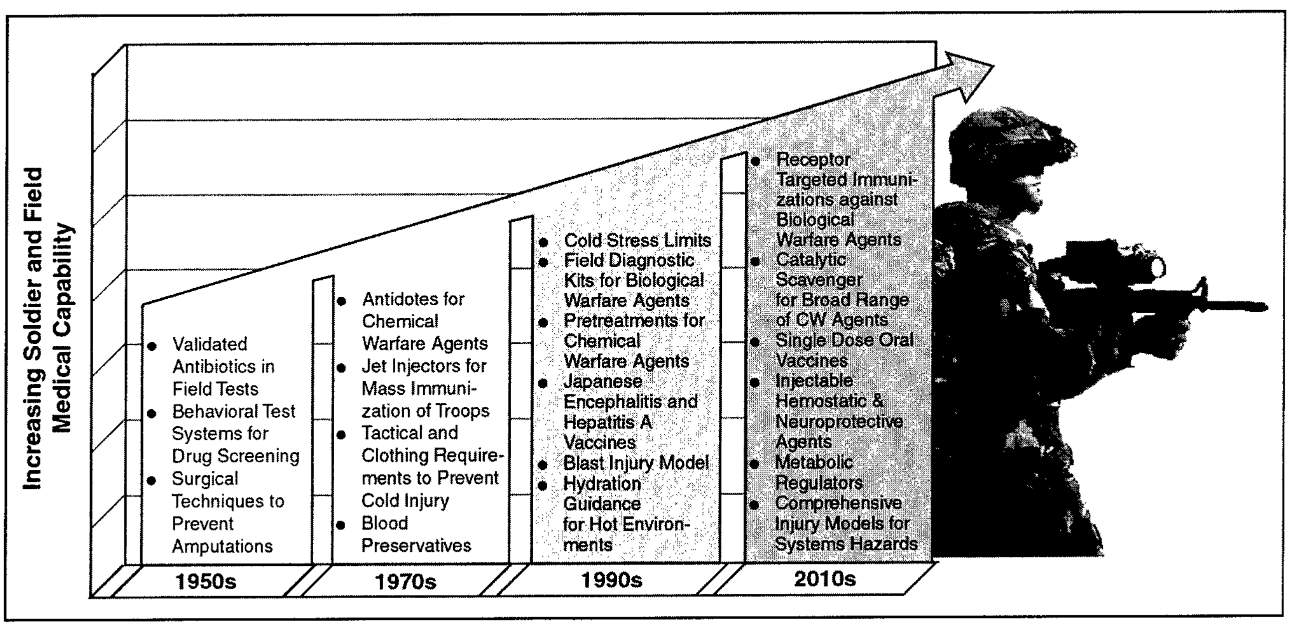


FIGURE V–20. PAYOFFS FROM BIOMEDICAL BASIC RESEARCH

enhanced combat effectiveness of the warfighter through efforts designed to improve soldier sustainability and survivability.

11 Biological Sciences

a *Strategy*

Basic research in the biosciences increases the ability to understand and manipulate those aspects of the biological world that impact soldier sustainment and survival and the ability to identify and characterize biological materials and processes for future exploitation in materiel systems. To plan and execute high-quality research relevant to Army needs in the biological sciences, the Army established the Biological Sciences Basic Research Coordination and Planning Group (BioCOG). BioCOG includes scientists from ARL/ARO, Army RDECs, MRMC, and the Army Corps of Engineers. Functioning as an advanced planning process team, this group laid the groundwork for the development of a 3-year strategy for focusing research program activity in the biosciences to emphasize an appropriate balance between (1) capture of breakthrough scientific opportunities from the biological sciences research community and (2) alignment with Army and DoD S&T objectives, including support of Army current and future demonstrations and fielded items where applicable. The program focuses on providing innovative capabilities to (1) increase economic and environmental affordability in Army materiel production, (2) lessen the logistics burden, and (3) prevent the deleterious effects of chemical, biological, and physical agents from interfering with Army operations. Implementing this strategy involves support of basic research in a number of subdisciplines—including biochemistry, biophysics, molecular biology and genetics, cell biology, microbiology, physiology, and pharmacology—encompassing studies at the molecular, cellular, and systems level (Figure V–21).

b *Major Research Areas*

Although aimed at enabling novel capabilities, program efforts in three major areas focus on providing solid scientific underpinnings for biologically based technology contributions to fulfilling Army operational requirements. Within the framework of Army Objective Force and Army Beyond 2010 goals, it is expected that biological sciences research will be making those contributions in force projection and protection, battle command, intelligence, maneuver, mobility, and logistics.

Biomolecular and Cellular Materials and Processes. Fundamental studies are required to define structure–function relationships and biochemical interactions for enzymes, receptors, and other macromolecules exhibiting mechanisms and properties uniquely relevant to synthetic and degradative pathways of interest to the military. Topics of interest include establishment of the foundations for manipulation and exploitation of biocatalysis, ribosomal and nonribosomal biosynthesis to enhance permissiveness toward elaboration of useful biomolecular structures, and cellular systems designed with "metabolic engineering" in mind. Also, research is needed to provide insight from nature on novel theoretical principles and mechanisms in sensory and motor function and on biological materials with extraordinary properties. This area includes not only initial molecular events, signal transduction pathways, and integrated information processing for the powerful sensing capabilities exhibited in the biological world, but also self-assembly processes, hierarchical structure formation, and functional characterization of biomolecular materials such as those with potential biomimetic utility for nanometer-scale fabrication or for energy and information transfer.

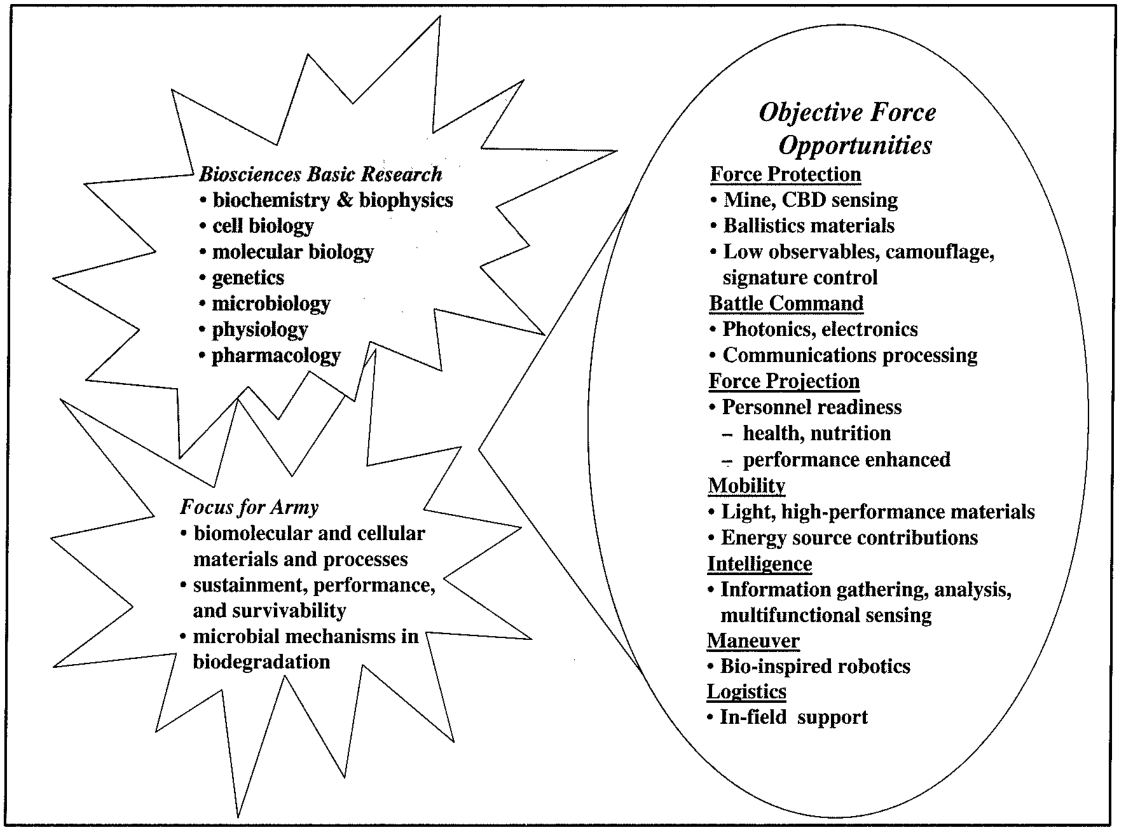


FIGURE V–21. BIOLOGICAL SCIENCES RESEARCH STRENGTHENS OBJECTIVE FORCE OPPORTUNITIES

Microbiology and Biodegradation. Basic research on the biochemical and physiological mechanisms underlying the biodegradative processes in normal, extreme, and engineered environments includes studies on organisms from extreme environments, the properties of materials that make them susceptible or resistant to biological attack, basic concepts for antifungals, mechanisms for the remediation of contaminated sites, analytical microbiology (including microbial signatures), and general microbial mechanisms with relevance to Army problems. Other areas of research include microbial communities, methods to study organisms that cannot be grown in the lab, and methods to enhance the stabilization of military materiel (including methods to prevent microbial growth).

Physiology, Survivability, and Performance. Basic research is required to understand how organisms respond and adapt to environmental signals and the strategies they employ to survive adverse environmental conditions; understand how organisms respond to and cope with stresses of various kinds, positively or negatively, at the molecular, cellular, or organismal level; and identify the molecular and genetic basis of adaptative behaviors, such as hibernation and sleep, and their long-term potential for application to the improvement of human performance and survivability. Also, as a way of accessing previously unknown or uncharacterized cellular processes related to physiology or homeostasis, basic research is needed in the area of host (primarily plants and lower organisms) response to viral invasion as well as how viruses usurp existing host resources and capabilities. Finally, research is needed in areas that show long-term potential for (1) reducing the degradation of human performance during extended operations or under adverse conditions, or (2) improving overall performance and survivability.

c *Potential Military Benefits*

Basic research in biological sciences promises significant payoff in defense against chemical and biological agents—an area of considerable importance to the Army not only for battlefield scenarios but also for counterterrorism, nonproliferation issues, and treaty verification. Areas of interest include (1) mechanisms of enzymatic or enzyme-mimetic catalysis for detoxification of threat agents, (2) modes of action of potential agents on physiological targets, with implications both for biologically based concepts for detection of threat agents and for protection based on a better understanding of agent–target interaction, and (3) rapid identification of biologicals using novel analytical techniques.

The potential is great for use of cellular genetic and biochemical manipulation in biotechnology for economically favorable and environmentally benign manufacturing processes, and for bioremediative strategies. Biosciences research will enable metabolic engineering and bioprocessing to make significant contributions to Army and DoD missions and to the commercial sector, including off-the-shelf products and processes for use by the military.

Research on biomolecular materials and processes enables the discovery of novel theoretical principles and products with extraordinary properties. These provide insight into the foundations of such phenomena as self-assembly, molecular recognition, catalysis, and energy transfer. Understanding will lead to unique military, industrial, and consumer applications in such areas as sensors, smart materials, robotics, low-observables technology, and biomimetic processing for composites. Likewise, the biological world offers many examples of exquisitely integrated signal transduction and multimodal information processing. Fundamental knowledge pertaining to how biological systems accomplish this will continue to have substantial impact on the design of engineered information systems.

Attempts to better understand the genetic and biochemical mechanisms in the diverse strategies of adaptation that organisms use to survive harsh environments or adverse conditions offer the hope of providing the soldier a means for coping with physiological stresses. Studies in food science provide the means to better understand nutrient conversion for cellular energy and neurotransmitter function and to enable control of microbial growth and stabilization of structural integrity during food processing, contributing not only to improved soldier satisfaction and enhanced long-term acceptability of combat rations, but also to improved soldier performance and endurance.

Experimental and conceptual advances made possible through fundamental studies in biological sciences already contribute to innovative technology outlooks for the future Army and are providing revolutionary ideas for the Objective Force. Biology is the mainstay of the Biomimetics SRO and offers new opportunities for insertion of technical breakthroughs via the nanoscience SRO as well as the emerging Army SROs on microminiature multifunctional sensors, signature management and control, and human performance enhancement.

12 Behavioral, Cognitive, and Neural Sciences

a *Strategy*

The Army behavioral, cognitive, and neural sciences (BCNS) program seeks a scientific understanding of the factors that can enhance or diminish human performance. The program focuses on the performance of individual soldiers operating in units. The BCNS program is executed by two agencies, the ARI for the Behavioral and Social Sciences and the Human Research and

Engineering Directorate (HRED) of ARL. Duplication of research is prevented through frequent meeting of the two agencies. Interservice coordination is effected through Reliance agreements. The research program is evaluated in the TARA review.

b *Major Research Areas*

Training. The training research program provides data, theories, and prototype technologies to improve distance learning, digitization, and fundamental knowledge about learning and information processing. A theoretical and computational understanding of cognitive processes is essential to the optimal design of training programs and, ultimately, the human–systems interface. Cognitive task analysis, multimedia design, and intelligent tutoring strategies can improve the speed at which an individual learns by a standard deviation or more. Decay of skills depends on skill type, training conditions, individual differences, and opportunities for rehearsal. Realism in a simulator is not the most important influence on the ability of an individual to learn and transfer skills to real equipment. Computer-generated forces are acquiring higher order cognitive characteristics, including planning and emotion, to provide more complex combat simulations. In these and many other ways, results from research are used to develop increasingly effective technologies for training soldiers to handle information overload and information warfare. Effective training is defined by its cost, the permanence of the training, and its ability to transfer to real equipment under realistic job conditions.

Personnel. The goal of the personnel research program is to understand the principles that support successful applied personnel research. The formation and maintenance of attitudes underlie recruitment, attitudes toward the Army, and personal opinions and behavior relevant to diversity issues. Aptitudes are central for the issues of selection and assignment of personnel. Results from this research are transitioned to applied research efforts and often have direct implications for policy.

Leadership. Research in the elements of leadership provides important theoretical frameworks, such as "recognition-primed decisionmaking," to improve command leadership performance and the ability to develop effective training in leadership skills. The history of warfare is replete with examples of less effective forces that have prevailed in battle as a result of more effective leadership. Effective leadership includes the ability to manage and inspire others, coordinate activities, train individuals and teams, and make decisions. Identification of the critical thinking skills supporting future command operating capabilities will guide the cognitive architecture of command and control in future battle groups.

Visual and Auditory Processes. The goal of this research program is to better understand visual and related processes such as divided attention, particularly as they impact on the use of head-mounted displays. Several unique Army issues are related to the use of head-mounted displays and the demands of task conditions and performance. This research will also support the Army's increasing emphasis on night operations, teleoperations, and the training and battlefield control systems afforded by advances in distributed interactive simulation. A better understanding of visual processes is needed if the Army is to effectively exploit advances in optics and infrared technologies.

Research in the auditory processes provides the knowledge to protect, support, and extend soldiers' auditory capability on the battlefield. The battlefield provides a unique challenge for audition. High noise levels and impulse noise that threaten auditory sensitivity compete with low-level sound signals that provide important information to the soldier. Well-designed

human–equipment interfaces must consider the characteristics of the auditory system for effective individual utilization of new technologies. The mathematical model of the ear, which is being considered as an international standard, allows more complete and timely exploration of these interactions.

Stress and Cognitive Processes. The stress and cognitive processes research program addresses the issue of how various types of stress affect individual functions. This research is accomplished through validated measures that are practical for use in the field, reflective of expected stressors (environmental, physiological, psychological), applicable to specific soldier tasks (physical, manual, perceptual, cognitive), and predictive of physical and cognitive task performance levels. The stress measurement battery provides a quantitative assessment of the effects of time constraints, noise, extreme climates, chemical decontamination operations, fatigue, and sustained operations on information assimilation and situational awareness. The collection of salivary amylase (Figure V–22) as a noninvasive physiological measure is accomplished in conjunction with the administration of psychological questionnaires to provide researchers with the appropriate diagnostic information necessary for a comprehensive stress assessment.

Soldier Interface. The goal of soldier interface research is to better understand the principles that enable the soldier and teams to manage the vast quantities of data that will flow across the digitized battlefield. This program, accomplished jointly with industry and universities as part of the federated laboratory project, will provide the Army with the ability to optimize the human component of battle management and utilize the information advantage provided by advanced sensors and improved communication.

c *Potential Military Benefits*

The overall goal of research in the behavioral, cognitive, and neural sciences is to optimize human performance and human–system interfaces. The research is guided by the requirements of the future battlefield. In this environment, a premium will be placed on soldier competence, initiative, and leadership. The combat effectiveness of the teams will be enhanced through an effective understanding of the battlefield and the ability to coordinate precision fire. This vision can be realized through improved cohesion, leadership, and more effective training using advanced simulation capabilities. Soldiers will operate equipment more effectively because of improved interfaces that consider their abilities and expectations. Finally, the confusion and stress of the battlefield will be controlled through more effective leadership and an improved understanding of the causes and effects of stress. The link between ARI and HRED research helps ensure that fielded systems are operable and cost effective.

E SUMMARY

The Army basic research program is an integrated internal (in-house laboratory) and external effort. The internal research is driven by mission needs; the external research is chartered to provide a balance between long-term extramural research objectives pursued through Army-funded academic COEs and industry-led federated laboratories, and unanticipated, more forward-looking research windows of scientific opportunity—pursued through the single-investigator program. ARL/ARO and the management at the Army's laboratories and RDT&E organizations deliberate and coordinate in partnership to establish, implement, and meet overall Army research objectives. Despite receiving only a small portion of DoD's basic research budget,

This kit is used to quantify stress levels within 5 minutes. This noninvasive physiological measure has been used in a variety of different military operations, particularly when investigating the effects of new technologies on soldier performance.

FIGURE V–22. SALIVARY AMYLASE FIELD ASSAY KIT

the Army derives the maximum return on investment from its research program through its high degree of integration. Table V–7 depicts how the scientific research areas described above support 17 technology areas recognized by the Army as being particularly important.

The research areas described in this chapter are dynamic and continuously updated. Programs are reviewed by multiservice organizations, Army battle laboratory personnel, peer reviewers, and coordinating groups established for each of the scientific areas. To illustrate the dynamic nature of the scientific areas, Table V–8 summarizes how certain research areas are receiving new or increasing emphasis and highlights recent accomplishments.

Much of the research supported by the Army is undertaken by distinguished scientists and engineers at American colleges and universities, as detailed in previous sections of this chapter. Not only does the Army benefit from their accomplishments, but they themselves receive honors bestowed on them by their peers. Table V–9 summarizes some of the awards received by individuals sponsored by the Army.

The Army's science base is an essential foundation for the technology on which the Army's ability to meet future threats depends. Research for the Army is performed by a blend of university

TABLE V–7. IMPACT OF BASIC RESEARCH AREAS ON ARMY MISSION AREAS

	(6.1) Research Areas											
Mission and Technology Thrust Areas	Mathematical Sciences	Computer & Informational Sciences	Physics	Chemistry	Materials Science	Electronics Research	Mechanical Sciences	Atmospheric Sciences	Terrestrial Sciences	Biomedical Research	Biological Sciences	Behavioral, Cognitive, & Neural Sciences
Aviation		○		●	●	○	●					
Command, Control, Communications, & Computers	●	●	●		○	●	○	●	○		○	○
Electronic Warfare			○									
Ground Combat and Tactical Systems				○	●	○	●		●	○		
Weapons	●	●	●	●	●	●	●	●	○		○	
Soldier and Personnel Technologies	○	○	○	●	●	○	●	○	○	●	●	●
Biomedical	○			○		●				●	●	○
Chemical/Biological Defense	○	○	○	●	○	○		●		●	●	
Engineering, Combat Construction, Mobility, & Countermobility				○	○	○	●	○	●			
Logistics	○	○		●	●		●		○	○	○	
Materials, Material Processes, & Structures	○	○	○	●	●	●	●	○	●	○	●	
Sensors & Electronics			●	○	○	●		●			○	
Battlespace Environment	○	●						●	●			
Biotechnology				○	●					●	●	

● Significant impact ○ Some impact

and in-house components that are uniquely suited to the Army's special requirements. Because of the fundamental role of the science base in shaping the Army's technological future, the Army is committed to strongly supporting basic research.

TABLE V–8. THE DYNAMIC NATURE OF BASIC RESEARCH PROGRAMS

New Emphasis	Increasing Emphasis	Accomplishments
	MATHEMATICAL & COMPUTER SCIENCES	
Image analysis Quantum computing	Nanotechnology	Extended front tracking method to complex surfaces in 3D Boundary integral methods for calculating photonic bandgaps in terminating structures Robust parsing strategy based on "supertagging" New data analytic method for pattern recognition
	PHYSICS	
Integrated sensory science Applications of atom optics Coherence-induced surface optics	Nanoscience Image analysis Photonic bandgap (PBG) materials Quantum computing	Fiber atom optics Squeezed photon states Multispectral sensor fusion Microwave soliton devices 2D photorefractive waveguides New PBG type of electromagnetic "skin"
	CHEMISTRY	
Polymers for signature management Molecular aging leading to materials failure	Flexible barrier polymers—soldier protection against CB threat Chemical agent detection—higher priority for chemical defense Novel chemistry for H_2 storage—to support compact power fuel cells	Combustion model for organo-phosphorus/nerve agents Thermal photovoltaic cavity power/weight increased by 4X Preliminary design of a cooled, silicon microgas turbine engine, reducing sintering time for vanadium catalysts from hours to minutes
	MATERIALS SCIENCE	
Prediction & control of microstructures Engineering of nanostructures	Heterogeneous & anisotropic materials Bulk metallic glass composites Si-based electronics hierarchical materials	Dynamic testing of bulk glassy composites Heteroepitaxy of GaAs on Ge on Si Electron holography of molecules Protein control of silica deposition Strength of micromachined silicon
	ELECTRONICS RESEARCH	
Multimode, multifunctional devices UV detectors Adaptive optoelectronic eye	Image analysis & terahertz electronics Low-power electronics with RF emphasis & low-energy electronics design for mobile platforms Demining & mine detection	Robust shape-preserving, multiscale, multiresolution image processing Er-doped III–N light emitters Quantum dot laser & detector Fundamental theoretical limits on multiuser channel capacity
	MECHANICAL SCIENCES	
Mesoscale machines Microadaptive flow control	Structural health monitoring of laminated composite materials Analysis & modeling of gear dynamics Plasma-propellant interaction, ignition, & combustion Multiscale models for composite solids	New method for damping transients during initial parachute deployment Liquid gun propellant intrinsic burn rate determination New efficient & accurate computational procedure for rotorcraft interactional aerodynamics flowfields New class of finite deformation cohesive elements for computation of material fracture & fragmentation
	ATMOSPHERIC SCIENCES	
Data analysis from new boundary layer instrumentation Field studies of stable boundary layers	Stable boundary layer	Model for short-range plume dispersion & concentration estimates Improved subgrid scaling in atmospheric surface layer

TABLE V–8. THE DYNAMIC NATURE OF BASIC RESEARCH PROGRAMS (CONT'D)

New Emphasis	Increasing Emphasis	Accomplishments
TERRESTRIAL SCIENCES		
No major new emphases	Terrain properties & characterization Terrestrial processes & landscape dynamics Terrestrial system modeling & model integration	Sediment transport capability added to CACS 2D distributed hydrologic model Recognition of three molecular-level forces in ice adhesion: ice-electrostatic interactions, hydrogen bonding, & van der Waals dispersion forces Development of a DEM-based numerical model that simulates erosion & deposition in response to a defined pattern of precipitation
BIOMEDICAL RESEARCH		
Mechanism of cellular apoptosis	Exploitation of genomic information Novel systems for administration of vaccines Rational drug design for drug discovery Free-radical scavengers Injectable hemostatic agents Metabolic regulators Neuro-imaging methods	Protease inhibitors for protection against sulfur mustard-induced injury Defined performance deficits in sleep deprivation using brain imaging studies Vaccines that prevent dysentery in animal models and human volunteers First demonstration of protection from naturally acquired malaria using a DoD-invented vaccine
BIOLOGICAL SCIENCES		
Integrated multifunctional sensing Sense & respond fundamentals for biomimetic function	Olfactory processes High-selectivity biodetection Genetic determinants of sleep, hibernation, & performance	Intense fluorescence signaling for biological detection Conformational switches for functional materials Characterization of genetics underlying physiology of hibernation Characterization of regulatory pathways for biodegradation
BEHAVIORAL, COGNITIVE, & NEURAL SCIENCES		
Team communication Perceptual processes	Multimodal interfaces Procedural skills	Effects of 3D auditory displays Procedural reinstatement theory

TABLE V–9. RECENT AWARDS RECEIVED BY SCIENTISTS AND ENGINEERS FOR RESEARCH SPONSORED BY THE U.S. ARMY

Individual	Affiliation	Award Received
Arnold, Prof. Frances	California Institute of Technology	1998 Lonza Centenary Biotechnology Prizes (award to graduate student Jeffray Moore)
Aspnes, Prof. D. E.	North Carolina State University	Member, National Academy of Sciences
Bazant, Prof. Zdenek	Northwestern University	Worcester Reed Warner Medal, American Society of Mechanical Engineering
Belytchko, Prof.	Northwestern University	Medal, International Conference on Computational Engineering & Science
Bhattacharya, Prof. Pallab	University of Michigan	1998 Guggenheim Award
Boyd, Prof. Ian	Cornell University	Lawrence B. Sperry Award, American Institute of Aeronautics & Astronautics
Bras, Prof. Rafael	Massachusetts Institute of Technology	National Water Research Institute Clarke Prize
Brown, Prof. Herbert	Purdue University	First H. C. Brown Award, American Chemical Society
Capasso, Dr. Federico	Bell Laboratories–Lucent Technologies	Wetherill Medal of the Franklin Institute
Chopra, Prof. Inderjit	University of Maryland	Member, Army Science Board
Conlisk, Prof. A. T.	Ohio State University	College of Engineering Lumley Research Award
Dordick, Prof. Jonathan	Rennselear Polytechnic Institute	Fellow, American Institute for Medical & Biological Engineers American Chemical Society Iowa Section Award
Gandhi, Prof. F.	Pennsylvania State University	American Helicopter Society Francois Xavier Bagnoud Award
Gellman, Prof. Sam	University of Wisconsin	American Chemical Society Arthur C. Cope Scholar Award
Grober, Prof. Robert	Yale University	1997 Packard Fellowship Award
Harwood, Prof. Caroline	University of Iowa	Lecturer, American Society for Microbiology Foundation (1998–2000)

TABLE V–9. RECENT AWARDS RECEIVED BY SCIENTISTS AND ENGINEERS FOR RESEARCH SPONSORED BY THE U.S. ARMY (CONT'D)

Individual	Affiliation	Award Received
Healy, Prof. Alice	University of Colorado	Fellow of the Society of Experimental Psychologists
Joshi, Prof. A.	University of Pennsylvania	1997 Research Excellence Award International Conference on Artificial Intelligence
Kadanoff, Prof. Leo	University of Chicago	1999 National Medal of Science
Kailath, Prof. Thomas	Stanford University	Member, Indian Academy of Engineering
Kimble, Prof. Jeff	California Institute of Technology	Max Born Award of the Optical Society of America
Leonard, Prof. J.	University of Connecticut	Commander's Educational Award for Excellence, Natick RDEC
Locke, Prof. Edwin	University of Maryland	Career Achievement Award, Academy of Management
McDowell, Prof. David	Georgia Institute of Technology	1997 Nadai Award, American Society Mechanical Engineering
Martin, Prof. Sandra	University of Colorado Health Sciences Center	National Science Foundation POWRE Award
Moskos, Prof. Charles	Northwestern University	First Recipient of Award for Public Understanding of Sociology, American Sociological Association & Winner of Washington Monthly Political Book Award
Parks, Prof. Leo	North Carolina State University	1997 Ken Keller Research Award (awarded to graduate student for outstanding thesis)
Pederson, Prof. Donald	University of California, Berkeley	Institute of Electronics & Electrical Engineers Medal of Honor
Plaut, Prof. R. H.	Virginia Polytechnic Institute	State of Virginia Council of Higher Education's 1998 Outstanding Faculty Award
Rao, Prof. C. R.	Pennsylvania State University	1997 American Statistical Association Distinguished Achievement Award & Hall of Fame, National Institution for Quality & Reliability
Reitz, Prof. Rolf	University of Wisconsin	Society of Automotive Engineers Fellow
Riviere, Prof. J. E.	North Carolina State University	Burroughs Wellcome Fund Distinguished Professor of Veterinary Pharmacology
Robinson, Prof. Stephen	University of Wisconsin–Madison	George B. Dantzig Prize—Triennial Award for Excellence in Mathematical Programming
Schmitz, Prof. Fredric	University of Maryland	Lifetime Achievement Award, American Helicopter Society, San Francisco Chapter
Segal, Prof. Mady	University of Maryland	Appointed to Congressional Commission on Military Training & Gender-Related Issues
Setlow, Prof. Peter	University of Connecticut	National Institute of Health Merit Award
Spencer, Prof. Peter	Oregon Health Sciences University	Joseph P. Kennedy, Jr., Fellow in the Neurosciences; Fellow, Royal College of Pathologists
Tirrell, Prof. David	California Institute of Technology	Fellow, American Institute of Medical & Biological Engineering Harrison Howe Award, American Chemical Society Chancellor's Medal, University of Massachusetts
Tsui, Prof. Daniel	Princeton University	1998 Nobel Prize in Physics
Waas, Prof. Anthony	University of Michigan	American Academy of Mechanics Junior Award
Wagerer, Prof. Ken	University of Florida	1997 Stone Will Award, American Chemical Society
Wan, Prof. K.-W.g	Pennsylvania State University	American Society of Mechanical Engineers Fellow
Weaver, Prof. John	University of Minnesota	1997 IR&D Scientist of the Year
Weinstein, Prof. Roy	University of Houston	1998 MRS/ISTEC Workshop Material & Device Award at the International Workshop
Wereley, Prof. Norman	University of Maryland	Army Young Investigator Award
Whitesides, Prof. George	Harvard University	1998 National Medal of Science
Wolf, Prof. Emil	University of Rochester	Honorary Doctorate of Science, Universities of Bristol & Laval
Yates, Prof. John	University of Pittsburgh	American Chemical Society Surface Science Adamson Award
Yau, Prof. Shing-Tung	Harvard University	1997 National Medal of Science

CHAPTER

VI TECHNOLOGY TRANSFER

CONTENTS

A ARMY TECHNOLOGY TRANSFER VI–1

B NATIONAL DEFENSE AND ECONOMIC COMPETITIVENESS (ARMY AND INDUSTRY) VI–2

1 **Small Business Innovation Research Program** **VI–2**
2 **Small Business Technology Transfer Program** **VI–3**
3 **Army Domestic Technology Transfer Program** **VI–4**
4 **Dual-Use Science and Technology Program** **VI–5**
5 **Commercial Operations and Support Savings Initiative** **VI–5**
6 **Independent Research and Development Program** **VI–6**

C TECHNOLOGY COOPERATION WITH NONPROFIT INSTITUTIONS VI–7

1 **Programs With Academia** **VI–7**
a University Research Initiative and Centers of Excellence VI–7
b National Science Foundation VI–7
2 **Historically Black Colleges and Universities and Minority Institutions Programs** **VI–8**
3 **Federally Funded Research and Development Centers** **VI–8**
4 **Outreach Programs** **VI–9**
a Women in Science and Engineering VI–9
b Youth Science Activities VI–9

D COOPERATIVE SCIENCE AND TECHNOLOGY VI–10

1 **Army Cooperation With Other DoD Organizations** **VI–10**
a Defense Advanced Research Projects Agency VI–10
b Defense Science and Technology Reliance VI–11
c Defense Threat Reduction Agency and Treaty Verification VI–11
d Ballistic Missile Defense Organization VI–12
e U.S. Special Operations Command VI–12
f Scientific Services Program VI–12
2 **Army Efforts With Other Federal Agencies** **VI–12**
a Activities With NASA VI–13
b Other Agencies VI–14
3 **Army Efforts With Industry** **VI–14**
a National Automotive Center VI–14
b National Rotorcraft Technology Center VI–15
c Institute for Creative Technologies VI–15

E INTERNATIONAL TECHNOLOGY LEVERAGING VI–15

1 **Vision** **VI–16**
2 **Role of International Programs** **VI–16**
3 **Country Capabilities and Trends Analysis** **VI–16**
4 **Global Technology and Research Capability Overview** **VI–17**

List of Figures

VI–1 Funding for University Research Efforts Includes Army Centers of Excellence and University Research Initiative Centers VI–7
VI–2 Army Outreach Programs Include Attracting Women Scientists and Engineers VI–9
VI–3 Army–NASA Joint Aeronautical Research Locations VI–13
VI–4 Rank Ordering of Country Capabilities VI–18

CHAPTER

VI TECHNOLOGY TRANSFER

A ARMY TECHNOLOGY TRANSFER

The Army technology transfer program promotes the transfer of technology to enhance both the economic competitiveness of the country and its military capability. Army laboratories and centers have technology, advanced facilities, and expertise that can be beneficial to more than national defense.

The initial requirement for technology transfer from federal laboratories was established in the Stevenson–Wiydler Act of 1980 (15 U.S.C. 3701 et seq.). Its intent was to maximize the benefit of taxpayer investment in federal R&D. The Federal Technology Transfer Act of 1986 (P.L.99–502) provided specific requirements, incentives, and authorizations for federal laboratories to engage in technology transfer.

Initial technology transfer programs emphasized spinoff applications from military technology to benefit the civilian economy. But with changes in the nature of the military threat, an increase in the rate of commercial technology development and good stewardship of government resources, DoD's emphasis has evolved to include "dual-use" and "spin-on" technologies. Dual-use technologies have both defense and nondefense applications.

The potential to enhance both private and military production bases is essential to achieve mutual cost reduction. Spin-on technologies are those developed outside the Army that have military applications. The Army continuously monitors developments in the commercial sector, looking for potential military applications.

This chapter describes the various components of the Army's technology transfer program, which employs a wide range of management, legal, and partnering approaches.

COMPONENTS OF THE TECHNOLOGY TRANSFER PROGRAM

Dual-use technology—national defense and economic competititiveness

Technology cooperation with nonprofit institutions

Technology leveraging programs

International technology leveraging

B NATIONAL DEFENSE AND ECONOMIC COMPETITIVENESS (ARMY AND INDUSTRY)

As defense spending declines, military and civilian technology and production bases must be merged wherever possible. Therefore, significant effort is devoted to tailoring Army R&D programs so that work is not duplicated in areas where civilian capability leads, and so that Army advances are shared where they have value to the civilian economy. This section highlights several programs designed to encourage development of dual-use capabilities and to hand off predominantly military capabilities that have civilian application. Each of these programs has enabling legislation.

1 Small Business Innovation Research Program

The Small Business Innovation Research (SBIR) program enables the Army to access the innovative technologies of small high-technology firms and to support those firms in conducting R&D innovative concepts. Of particular interest are R&D efforts leading to solutions to Army- and defense-related scientific or engineering problems that also permit small businesses to commercialize their developed technologies within the private sector.

As mandated by public law, the SBIR program is intended to (1) stimulate technological innovation, (2) increase small business participation in federal R&D, (3) increase private sector commercialization of technology developed through federal R&D, and (4) foster and encourage participation in federal R&D by businesses that are owned by women and socially and economically disadvantaged individuals. Firms participating in SBIR must be "small businesses" (under 500 employees) as defined by the Small Business Administration, U.S.-based, and for-profit.

Congressional mandate requires that all federal agencies with an annual extramural R&D budget exceeding $100 million participate in the SBIR program. The SBIR budget is computed as 2.5 percent of the agency's extramural R&D budget. The Army SBIR budget for FY00 was approximately $110 million.

Each year, in cooperation with other DoD components, the Army generates and publishes a set of high-priority topics in an SBIR solicitation and invites small businesses to submit proposals dealing with these topics. The topics reflect the user community's interests and future operational capabilities (FOCs) as expressed by TRADOC.

The SBIR program has three phases. Phase I determines the scientific or technical merit and feasibility of a proposed concept and typically requires up to 6 months to complete. Approximately 1 in 10 proposals is selected for award. Those Phase I performers showing the best promise may be invited by the Army to submit Phase II proposals. Phase II is a 2-year effort covering the main R&D work. Approximately one-third to one-half of the invited Phase II proposals are selected for award. Interim funding of up to $50,000 (total cumulative funding remains at $850,000) is provided in the Army SBIR program to provide companies a smooth transition between Phase I and Phase II. Phase II projects develop well-defined products or services that have relevance to the Army, DoD, and the private sector.

Phase III is the last step in the SBIR process. In Phase III, the small business is expected to market and sell the products or services developed during Phase II outside the SBIR program. No SBIR funding is provided in Phase III; however, the firm is free to pursue non-SBIR government

follow-on contracts (sole-source or otherwise), or a leveraged combination of both non-SBIR government and private sector funding.

The Army is the Executive Agent for coordination of the chemical and biological defense (CBD) program. Starting in calendar year 1998, the Army, with the cooperation of the Navy and Air Force, developed the first set of 15 CBD SBIR solicitation topics. Then as now, CBD SBIR topics touch on both medical and nonmedical aspects of CBD. The annual CBD SBIR budget has remained at approximately $6 million. As lead agency, the Army coordinates tri-service efforts related to developing solicitation topics and the receipt, evaluation, selection, and award of SBIR Phase I and II proposals under this program.

Army SBIR Program Web Sites
http://acq.osd.mil/sadbu/sbir
http://www.aro.army.mil/arowash/rt/sbir.htm

2 Small Business Technology Transfer Program

The Small Business Technology Transfer (STTR) program was established by Congress as a 3-year pilot program beginning in FY94 by the Small Business Research and Development Enhancement Act of 1992 (P.L. 102–564) and has subsequently been reauthorized by Congress. The STTR program is a competitive three-phase program designed to energize small businesses to partner with researchers at universities, nonprofit research institutions, or federally funded R&D centers (FFRDCs). The goal is to rapidly move innovative concepts, emerging technologies, and cutting-edge research out of the laboratory and into the commercial marketplace. A minimum of 40 percent of the R&D work in terms of STTR contract dollars must be performed by the small business and not less than 30 percent by the research institution. The small business is the prime contractor and has overall responsibility for managing and performing the work. The DoD STTR solicitation, released during the second quarter of each year, contains broad topics based on critical technologies reflecting the Army's mission and emphasizes potential commercialization and dual-use applications. Eight Army topics were included in the FY00 STTR solicitation.

The STTR Phase I, sometimes referred to as the "proof-of-principle" phase, is designed to determine the scientific and technical merit, commercial potential, and feasibility of the proposed cooperative effort. Phase I awards are for up to $100,000 and may not exceed 1 year in execution. Based on the performance and results during Phase I, the Army invites the businesses with the most promising efforts to submit Phase II proposals. The best of these are selected and awarded contracts to continue their R&D in Phase II. Phase I awardees who obtain independent third-party commitments of funds for Phases I and II are eligible for the STTR Fast Track and may receive matching "interim gap" funds (between Phases I and II) as well as Phase II STTR funds. Phase II awards are for up to $500,000, not to exceed 2 years in execution. In Phase III, the small business–research institution teams are expected to use private capital or non-STTR government funds, or both, to commercialize the results of their STTR-sponsored research.

All federal agencies with an extramural research, development, and acquisition (RDA) budget exceeding $100 million have STTR programs. The STTR set-aside is 0.15 percent of an agency's extramural RDA budget. The STTR budget for FY00 is $6.9 million and is anticipated to remain steady in the outyears.

STTR and SBIR Web Site
http://www.acq.osd.mil/sadbu/sbir

3 Army Domestic Technology Transfer Program

The Army Domestic Technology Transfer (ADTT) program seeks to create an environment that both fosters and facilitates the transfer of technology between military and civilian applications.

The initial formal requirement for technology transfer from federal laboratories was the Stevenson–Wydler Act of 1980 (15 U.S.C. 3701 et seq.). Its intent was to maximize the benefit of taxpayer investment in federal R&D. The Federal Technology Transfer Act of 1986 (P.L. 99–502) provided specific requirements, incentives, and authorities for federal laboratories to engage actively in technology transfer. It gave the director of each federal laboratory the authority to enter into cooperative R&D agreements (CRDAs) and to negotiate patent license agreements (PLAs) for inventions made at their laboratories.

The National Technology Transfer and Advancement Act of 1995 (P.L. 104–113) amends these previous laws to provide additional incentives, encouraging technology commercialization for both industry partners and federal laboratory inventors. This new law seeks to promote industry's prompt deployment of inventions created in a CRDA by guaranteeing the industry partner sufficient intellectual property rights to the invention and providing increased incentives and rewards to laboratory personnel who create the inventions.

CRDAs are only one of several mechanisms used for technology transfer. The CRDA is an agreement to cooperate and share intellectual property rights resulting from joint R&D efforts. It makes the technology, facilities, and people of Army laboratories available to commercial partners at an early stage of development; provides a direct benefit to the Army's mission from the partners' efforts; and, perhaps most importantly, encourages direct communication between scientists and engineers of the two sectors. Since CRDAs are not a procurement (the government does not provide funding for services or products), military procurement procedures are not required. CRDAs should be established to develop technology with obvious value, and should either commercially improve the U.S. competitive position or serve the public good, as in health, educational, or environmental areas. CRDAs should also be sought in technology areas of strategic importance to the laboratory or center.

PLAs are also an important mechanism for commercializing inventions developed in Army laboratories. Each laboratory maintains a collection of patents covering inventions by its scientists and engineers, and markets those inventions with potential commercial application. When licensed and commercialized, the inventions benefit consumers with new or improved products. Royalties are shared by the inventors (who get the first $2,000 and, thereafter, 20 percent of royalties received) and the laboratory (which keeps most of the remainder). The ADTT program is initiating more aggressive patent marketing strategies to increase the level of Army patent licensing.

Each Army laboratory and research, development, and engineering center (RDEC) has an Office of Research and Technology Applications (ORTA) to actively seek technology transfer opportunities and to serve as a point of contact for potential users of its technology. The functions of an ORTA include assessment of laboratory technology that might have commercial applications, assistance to state and local governments, and development of CRDAs and PLAs in conjunction with private sector and laboratory technical and legal staffs. The ADTT program is intended to work through the decentralized but coordinated activities of the ORTA at each Army laboratory and center.

Technology Transfer in Medical R&D. The Army medical R&D program has the mission to sustain and protect the health and lives of U.S. warfighters. Many military medical products have a direct application to worldwide civilian medical care. Examples include Dr. (MAJ) Walter Reed's work in eradicating yellow fever and the more recent development of the Hepatitis B vaccine.

Because of the cost required to conduct clinical trials and other tests necessary for the development of drugs, vaccines, and medical devices, it is impossible for the Army Medical Research and Materiel Command (MRMC) to totally support all required efforts. Many products developed by MRMC are intended to prevent or treat infectious diseases found primarily in third-world countries. These are the places to which the Army deploys; however, the existing civilian infrastructure cannot support treatment of the civilian population. Therefore, the commercial market for these products is limited. For this reason, MRMC has established an extraordinary number of CRDAs with civilian organization. MRMC is able to provide a world-class technology base research program and limited advanced development funding to reduce the overall risk while the civilian organizations are able to bring additional funding and expertise necessary for advanced development and ultimate FDA approval.

The MRMC is increasing its commitment to technology transfer by providing additional emphasis to the patent program. Patents of intellectual property are a crucial end product for the technology base because they allow industry to partner with MRMC in order to complete the development process without fear of immediate competition. This reduces the risk to the corporate partner. Advantages to MRMC include the recognition of the excellence of its scientific personnel, a return on investment in the form of royalties, and most importantly the development and fielding of quality medical products intended to sustain and protect the lives of America's sons and daughters.

4 Dual-Use Science and Technology Program

MINIMUM REQUIREMENTS OF THE DUS&T PROGRAM

Development of a dual-use technology that meets a military need and has sufficient potential for a commercially viable production base

50 percent of the cost must be paid by nonfederal participants

Industry awards are based on competitive procedures and solely on merit

Projects must be awarded using technology investment agreements

Projects must result in the development of a technology, not the application of a technology

The Dual-Use S&T (DUS&T) Program was established by the National Defense Authorization Act of FY98. Its two primary objectives are to jointly fund the development of dual-use technologies with industry, and to make the development of dual-use technologies with industry a preferred procurement alternative throughout DoD.

Two elements critical to the success of the DUS&T Program are industry cost share, which helps ensure the commitment of commercialization, and the use of technology investment agreements (i.e., other transactions and cooperative agreements). The use of these instruments attracts commercial firms that would otherwise not do business with DoD.

DUS&T WEB SITE

http://www.dtic.mil/dust

5 Commercial Operations and Support Savings Initiative

The Commercial Operations and Support Savings Initiative (COSSI) mission is to reduce operation and support (O&S) costs by routinely inserting leading-edge commercial technologies into fielded military systems. This approach permits DoD to reduce its inventories, obtain rapid

delivery from commercial suppliers, and upgrade through spares as new technology becomes available. COSSI solicits ideas from industry on ways to use commercial technologies to reduce the O&S costs of fielded systems. Once opportunities are identified, COSSI shares the costs of the nonrecurring engineering and qualification needed to adapt and successfully insert those commercially available technologies for use in a military system.

COSSI WEB SITE
http://www.acq.osd.mil/es/dut/

6 Independent Research and Development Program

IR&D activities are planned, performed, and funded by companies in order to maintain or improve their technical competence or to develop new or improved products. Industry IR&D efforts amount to more than $2 billion annually. A significant portion of a company's annual IR&D expenditures and its companion bid and proposal costs can be recovered later in the overhead portion of its contracts with commercial concerns and with DoD. The FY92 Defense Authorization Bill simplified the procedure used to reimburse companies for relevant IR&D work, and now contractors can be reimbursed for up to 100 percent of their IR&D expenditures that meet "potential interest to DoD" criteria.

Prior to FY93, company IR&D programs were assigned to a lead service for technical review and cost-recovery negotiations. The current law eliminates these assignments and focuses on use of industry's significant IR&D technology resources through technical interchange meetings, which are arranged by mutual agreement between the company and the government to discuss technology or product development projects. These meetings promote face-to-face technical interaction between contractors and the government, provide feedback to companies so that IR&D activities are aligned with future government needs, and permit government participants to visit the contractors' facilities and view operations. Company and government personnel are free to continue frequent informal dialogues and technical information exchange even though they no longer maintain formal relationships.

CRITICAL FOR REIMBURSEMENT TO INDUSTRY IR&D

Enabling superior performance of future weapon systems and components

Reducing acquisition costs and life-cycle costs of military systems

Strengthening the U.S. defense industrial and technology base

Enhancing U.S. industrial competitiveness

Promoting the development of critical technologies (as identified by DoD)

Increasing the development of technologies useful in both the public and the private sectors

Developing efficient and effective technologies for achieving environmental benefits

The Defense Technical Information Center maintains a restricted IR&D web site containing current IR&D technology developments. This permits Army IR&D managers to better target IR&D projects of interest, vector project writeups to local scientists and engineers, and arrange technical information exchange meetings.

Improved communications between industry and government on IR&D is at the heart of successful leveraging of IR&D, and continues to be emphasized through frequent interaction of Army leadership and industry IR&D representatives.

C TECHNOLOGY COOPERATION WITH NONPROFIT INSTITUTIONS

Universities have traditionally performed a major part of the nation's long-term basic research. Since the 1940s, the Army has supported academic work in areas of potential military interest. In response to evolving social, economic, and budget realities, Army support to universities has emphasized Army problems and efforts to apply research results to commercial or dual-use products. It has also emphasized support to people and institutions traditionally under-represented in the national scientific and engineering efforts. The Army is increasing its efforts to support interest in science and engineering careers in colleges and universities, high schools, and elementary schools.

The Army cooperates with nonprofit institutions (including universities) by means of CRDAs and PLAs. The Army STTR program uses small businesses to commercialize technology developed in these institutions.

The Army is the government sponsor for two FFRDCs and, as appropriate, uses the unique capabilities of FFRDCs sponsored by others.

1 Programs With Academia

The Army's 6.1 program, approximately half of which supports basic research at universities (Chapter V), is a key leveraging mechanism. The Army also maintains a European Research Office and supports a small amount of research at universities in Europe and Japan in order to gain access to unique foreign capabilities (Section E).

a *University Research Initiative and Centers of Excellence*

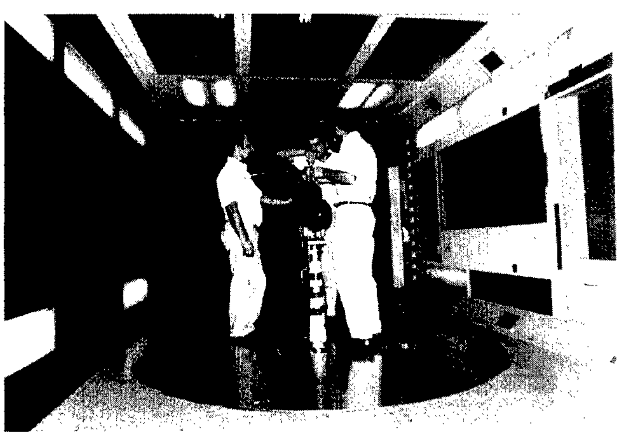


FIGURE VI–1. FUNDING FOR UNIVERSITY RESEARCH EFFORTS INCLUDES ARMY CENTERS OF EXCELLENCE AND UNIVERSITY RESEARCH INITIATIVE CENTERS

In addition to providing support to individual researchers, the Army sponsors research through two university-centered programs: the Army centers of excellence (COEs) and the series of DoD projects known as the University Research Initiative (URI). Both address specific Army needs (Figure VI–1). The URI's science and engineering education programs also address this country's need to increase its pool of scientists and engineers by supporting nearly 400 science and engineering graduate students annually.

University COEs provide Army support to graduate-level research and education. The centers have attracted additional sources of support; therefore, the Army's investment in these centers is highly leveraged. Through the COEs and URI, the Army participates with more than 30 American universities.

b *National Science Foundation*

Through a memorandum of understanding, the Army and the National Science Foundation (NSF) formed a consortium with eight universities to attack critical problems in high-speed microelectronics, millimeter waves, and communications research. The Army Research Labora-

tory (ARL) is an industrial board member of the Software Engineering Research Center sponsored by NSF. NSF provides grants, and the Army provides access to what is considered DoD's best microelectronics fabrication facility. While there, students and their mentors conduct research that benefits academia and the government.

2 Historically Black Colleges and Universities and Minority Institutions Programs

The Army has long recognized that historically black colleges and universities (HBCUs) and minority institutions (MIs) are a national resource with high enrollments of underrepresented minorities. As early as 1980, the Army Research Office (ARO) offered special initiatives to HBCUs and MIs to encourage their participation in its basic research programs. By the early 1990s, HBCU and MI programs were receiving increased attention at the highest levels of the Army, and a 1992 Army Science Board report recommended several initiatives aimed at enhancing the participation of HBCUs and MIs in Army R&D programs. The objectives of the initiative are to (1) enhance the ability of HBCUs and MIs to participate in defense research activities, and (2) increase the number of minority graduates in science, engineering, and mathematics (SEM).

ARMY POLICY FOR HBCUs/MIs

At least 5 percent of RDA funds going to higher education institutions are awarded to HBCUs or MIs

Each RDEC/laboratory is to foster a linkage agreement with an appropriate HBCU or MI

All new Army COEs are to have an HBCU or MI member

Each Army COE is to have a proponent laboratory/ RDEC, which provides the COE Executive Advisory Board Chairman

HBCUs and MIs also received increased attention from DoD and, pursuant to legislation (P.L. 101–510 §832), the DoD Infrastructure Support program for HBCUs and MIs was initiated. Management responsibilities for the program were assigned to ARO. Now in its seventh year, this tri-service program supports infrastructure enhancements aimed at strengthening SEM programs at HBCUs and MIs. These include, for example, the acquisition of instrumentation, collaborative research projects between Army laboratories and HBCUs and MIs, and various enhancements in SEM education. Although immediate benefits are to the institutions, long-term benefits will be to defense research activities as the program's objectives are realized.

Other initiatives designed to tap the resources of HBCUs and MIs and facilitate long-term benefits for the Army include:

- ARO established two HBCU and MI COEs for SEM education, one supported by ARO funds, the other by DoD funds. Students receive scholarships, stipends, mentoring, and internships. More than 350 students are expected to participate over a 5-year period.
- ARL established the Science and Technology Academic Recognition System fellowship program. Recipients of these fellowships receive tuition and expenses for the senior year of undergraduate study and 2 years of graduate study. The fellows are employed by ARL during the summers. Upon completion of graduate programs, they are required to work with ARL or pursue work in other areas of the federal government. The program targets undergraduates who attend HBCUs or MIs, but may also support graduate students at any accredited university.

ARO periodically publishes brochures highlighting accomplishments of the AMC HBCU and MI programs.

3 Federally Funded Research and Development Centers

FFRDCs, which perform, analyze, integrate, support, or manage basic or applied R&D, receive at least 70 percent of their financial support from the federal government. FFRDCs have greater access to government and supplier data, employees, and facilities than in a normal contractual

relationship. A master list of FFRDC activities is maintained by the NSF. The Army is the government sponsor for two FFRDCs: the Arroyo Center, a research division of Rand in Santa Monica, CA; and the Mitre Corporation's Command, Control, Communications, and Intelligence (C^3I) Division in Washington, DC.

Staff at the Arroyo Center perform studies and analyses for the Army. The mission of this FFRDC is to provide objective and independent analytical research on major Army policy, management, and technology concerns, with an emphasis on mid- to long-term problems. Efforts include policy and strategy analyses; research within the framework of the Army's future force needs and employment concepts; analyses and testing of alternative policies for manning, training, and structuring the Army of the future; analysis of issues associated with future readiness and sustainability; and studies in applied technology.

The Mitre C^3I FFRDC has two divisions: the Mitre Bedford Division, sponsored by the Air Force; and the Mitre Washington Division, sponsored by the Army (the "primary sponsor" is the Office of the Secretary of Defense). The mission of this FFRDC is to conduct studies and analyses and provide system engineering support and laboratory experimentation based on sponsors' requirements. Mitre conducts its own in-house R&D, tailoring the programs to sponsors' missions. An important link between the Air Force and the Army, Mitre provides an objective technical basis for the conception, analysis, selection, design, and evaluation of information and communications systems.

4 Outreach Programs

Studies by NSF and the National Academy of Sciences have indicated that in order to meet future scientific and economic challenges, the nation will need to attract and retain more students in degree completion programs in SEM. Approximately 70 percent of the adults entering the workforce between now and the 21st century will be women and minorities; yet, women and minorities are two groups still underrepresented in high tech fields. To counteract this trend, DoD task force studies have urged the creation of intervention programs designed to increase the availability of scientific, engineering, and technical skills in the DoD workforce.

a *Women in Science and Engineering*

The Army has outreach activities whereby it employs women college students studying engineering and the sciences in a cooperative education program that alternates school and work cycles. High school and college summer employment opportunities are also available (Figure VI–2). In addition, there are employment programs for women instructors in high schools and higher education who are interested in maintaining their technical expertise

FIGURE VI–2. ARMY OUTREACH PROGRAMS INCLUDE ATTRACTING WOMEN SCIENTISTS AND ENGINEERS

b *Youth Science Activities*

Many Army laboratories have outreach programs that actively support innovative ways to improve S&T education. There are adopt-a-

school (more than 90 within the Army), education partnerships, and student and faculty employment programs. Services provided by hundreds of Army scientists and engineers have helped improve science, mathematics, and technology education through technical lectures, career education, judging science fairs, field trips, mentoring student research projects, library and computer support, lending or donating surplus equipment, and teaching classes or assisting in the development of courses and materials.

D COOPERATIVE SCIENCE AND TECHNOLOGY

Army S&T funding is less than 1 percent of the total national investment in R&D; therefore, the Army must leverage external R&D to meet its warfighting needs. This R&D comes from other federal government organizations, universities, nonprofit organizations, U.S. industry, and foreign sources. The Army's goal is to form cooperative programs with these sources, sometimes involving cost sharing. In other cases, the Army seeks to influence the direction of development or maintain a "smart buyer" capability within the Army.

This section describes the Army's approach to technology leveraging with the major U.S. external sources of technology. (Section E describes its approach to leveraging foreign sources.)

1 Army Cooperation With Other DoD Organizations

Many Army S&T activities are coupled with programs of the other services or with other DoD organizations. The major organizations with which the Army interacts are Defense Science and Technology Reliance, the Defense Threat Reduction Agency (DTRA), the Defense Advanced Research Projects Agency (DARPA), the Ballistic Missile Defense Organization (BMDO), and the U.S. Special Operations Command (USSOCOM). Working relationships between Army and agency technical staffs have included coordinated program planning, parallel funding, and, in some cases, joint agency and Army program management by Army S&T organizations.

a *Defense Advanced Research Projects Agency*

On 28 February 2000, DARPA and the Army signed a memorandum of agreement (MOA) establishing a collaborative program for the design and competitive demonstration of the Future Combat Systems (FCS). The objective of this jointly funded program is to define the FCS design concepts and concept of operations. FCS envisions a lightweight, multifunctional combat "system of systems" that is lethal, mobile, self-sustaining, and survivable for 2012–2055 and beyond. This program will (1) define and validate FCS design and operational concepts using modeling and simulations (M&S) and surrogate exercises; (2) fabricate and test the FCS Demonstrator with three or more of its desired functionalities (direct fire, indirect fire, air defense, reconnaissance, command and control on the move, ability to transport troops) suitable for system development and demonstration (SDD) and production; and (3) develop radically innovative enabling technologies for use in the Demonstrator. Under this innovative agreement, DARPA and the Army are sharing responsibility and funding for transforming the Army into a lighter, more lethal and mobile force—one that will be strategically responsive and dominant across the full spectrum of operations.

The program will leverage and complement separate DARPA and Army technology efforts. DARPA's role is to identify and validate the right mix of enabling technologies. DARPA and the Army will co-fund the design concept and concept of operations as well as the M&S and surrogate exercise validation. They will also co-fund the FCS design (suitable for transition to SDD), Demonstrator fabrication and testing, and development of selected enabling technologies. The Army may separately focus and fund its selected enabling technologies as well as additional functionalities in the Demonstrator. DARPA will be responsible for overall management of the program through the end of the demonstration phase in FY05. The program will then transition to the Army for the SDD phase in FY06.

In addition to pursuing technology development, DARPA has awarded multiple "Other Transactions for Prototypes"-type agreements to industry for developing FCS design concepts and concepts of operation. Multiple awards are expected to be made to industry teams for the initial 24-month design concepts phase. Each team will conduct technology assessments, analyze requirements, design trade studies, and examine risk reduction activities for various FCS options. Each of the teams will develop a system design and concept of operations covering all the FCS capabilities. In a second phase, there will be limited competition among the previous contractors for the design of the FCS to a level suitable for transition into an SDD program and for the fabrication and testing of the Demonstrator. An "industry day" to apprise industry of the FCS program was held on 11 January 2000, and a final solicitation was issued on 31 January 2000. The concept phase awards were made on 9 May 2000.

b *Defense Science and Technology Reliance*

The Army fully supports the Defense S&T Reliance organization. Defense S&T Reliance, under DDR&E's Deputy Under Secretary of Defense (Science and Technology), provides a framework and assessment process to strengthen cooperation among the services and agencies to enable the DoD S&T community to work together to enhance the overall DoD S&T program and eliminate unwarranted duplication. Defense S&T Reliance has been refined and improved over the past 8 years. It provides the S&T blueprint for the 21st century through coherent DoD-wide planning, document preparation, and review process. Defense S&T Reliance provides input to a number of important management functions and planning processes, including the budget planning process and the development of technology investment plans.

DDR&E/RELIANCE PUBLICATIONS
Defense Science and Technology Strategy
Basic Research Plan
Joint Warfighting Science and Technology Plan
Defense Technology Area Plan
Defense Technology Objectives for the JWSTP and DTAP

c *Defense Threat Reduction Agency and Treaty Verification*

The Chemical Weapons Treaty includes a provision for compliance monitoring via onsite inspection. DTRA is the DoD executive agent for RDT&E programs related to treaty verification and compliance, while the Army is the DoD executive agent for chemical and biological defense. Accordingly, the Army and DTRA have created a working environment via an MOA in which the Army is the lead performer for sampling methodology and audit trails, chemical agent sensor assessments, protective devices and equipment, and field demonstrations of available technology. The U.S. Army Edgewood RDEC coordinates Army technology efforts in this area. The program is funded by DTRA. The MOA was signed in FY90, and detailed technical planning and implementation continues.

d *Ballistic Missile Defense Organization*

BMDO is the focal point for policy and program formulation. The operational aspects of BMD work are performed through the BMD executive agents and their research facilities and service commands at various locations throughout the United States.

e *U.S. Special Operations Command*

Established in 1987, USSOCOM unifies all continental-based Special Operations Forces (SOF) under a single commander. Its unique missions include counterproliferation of weapons of mass destruction, combating terrorism, foreign internal defense, special reconnaissance, direct action, psychological operations, civil affairs, unconventional warfare, and information operations. Collateral Special Operations activities include humanitarian assistance, security assistance, personnel recovery (combat and civilian search and rescue), counterdrug, coalition support, countermine, and special activities.

An assessment by USSOCOM, to include the U.S. Army Special Operations Command, has shown that many SOF technology needs and requirements are being or can be addressed in Army laboratories and centers, and that the SOF community can maximize its return on investment by coupling with current and planned Army technology efforts. One such example is the Land Warrior and Future Warrior architecture. USSOCOM has also participated in ACTDs, intercommand seminars, exercises, and the Army's Technology Seminar Games. The SOF participates in the Army's Future Soldier System Tech Base Executive Steering Committee, and reviews Army work packages to identify the projects of most value for satisfying SOF materiel needs.

f *Scientific Services Program*

ARO monitors this competitively awarded program, consisting of a short-term analysis service (STAS), a laboratory research cooperative program, conferences, workshops, and symposia, as well as the Summer Faculty Research and Engineering Program (SFREP), the Summer Associateship Program for High School Science and Mathematics Faculty, and the Post-Laboratory Research Cooperative Program/Post-Summer Faculty Research and Engineering Program.

STAS, the largest program, annually processes between 200 and 300 projects that originate in all three services and other government agencies. STAS's objective is to competitively award short-term projects that complement government expertise to academic or small-business scientists. Awards are usually less than $100,000 each (although special requests up to $250,000 are considered), are less than a year's duration, and are usually made within 30 days of receipt of the work order. Under the SFREP, about 150 faculty members are placed in Army laboratories or centers each year. The program annually awards $10 to $15 million.

2 Army Efforts With Other Federal Agencies

The Army must work with other government agencies to fully leverage its R&D efforts. The Army cooperates with many agencies to accomplish missions of mutual interest, obtain access to unique capabilities, and provide other agencies with access to unique Army capabilities. A major effort with the National Aeronautics and Space Administration (NASA) allows the Army to leverage capabilities that are closely related to Army needs.

a *Activities With NASA*

In 1965, the AMC and NASA signed an agreement for joint participation in aeronautical technology related to Army aviation. The original agreement, issued to what is now the Aviation and Missile Command (AMCOM), was an open-ended permit to use NASA's 7- by 10-foot subsonic wind tunnel at NASA's Ames Research Center. The agreement now includes the ARL Vehicle Technology Center at NASA's Langley and Lewis Research Centers, and two joint research program offices at Langley. The agreement also includes elements of ARL, AMCOM, and the Communications–Electronics Command, as illustrated in Figure VI–3. This cooperative arrangement gives Army engineers direct access to NASA's world-class research facilities at very low cost. For example, although the Army has access to facilities worth more than $1 billion at the Ames Research Center alone (with an annual operating cost of more than $60 million), the Army directly incurs less than 1 percent of the annual cost.

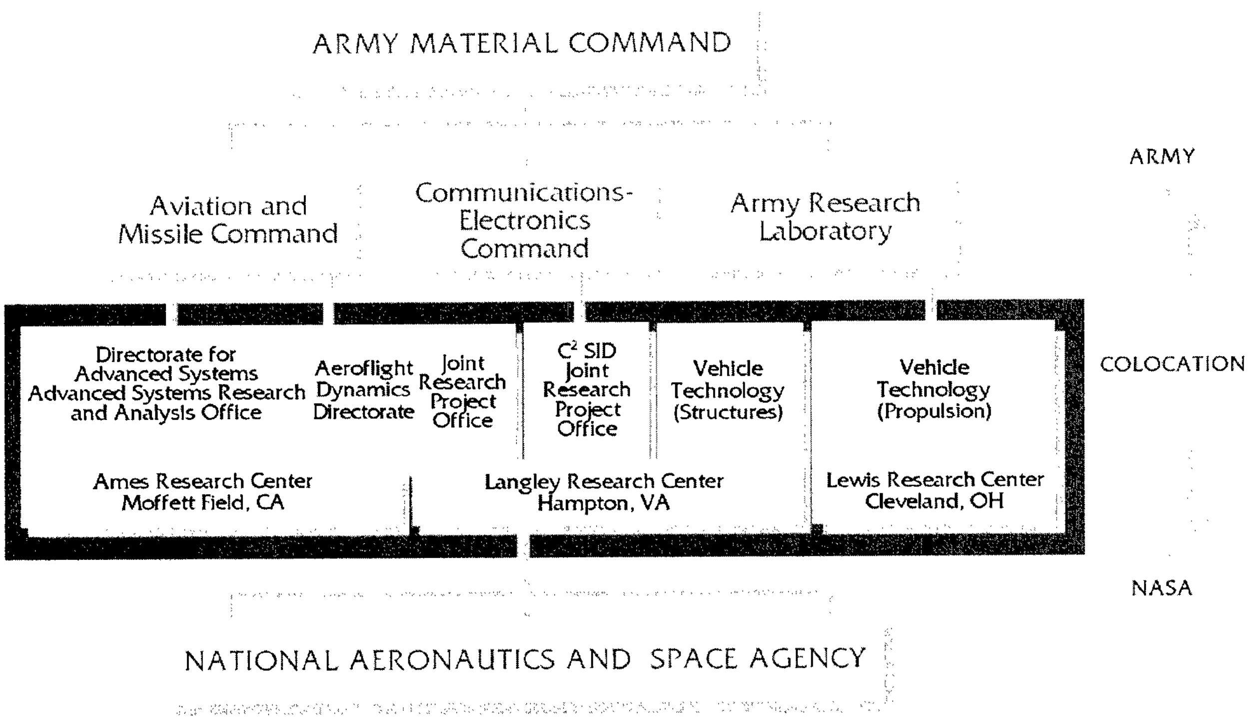


FIGURE VI–3. ARMY–NASA JOINT AERONAUTICAL RESEARCH LOCATIONS

Army scientific and engineering personnel may be assigned within the NASA organization, but they work on programs of Army interest as negotiated by the Army director with their NASA division or branch chiefs. This ensures that Army resources are focused on Army priorities and permits the Army and NASA to accomplish more with less.

Thirty years of Army–NASA cooperation has allowed the Army to leverage NASA resources and programs, and has contributed to the advancement of an integrated civil and military technology base.

b *Other Agencies*

A dozen years of joint research on robotics with the Department of Commerce's National Institute of Standards and Technology (NIST) has led to success in the application of flexible computer architectures to DoD unmanned ground vehicle testbeds for hazardous military missions, such as reconnaissance. This experience has allowed the Army and NIST to collaborate on civil programs, such as the Department of Transportation's Intelligent Vehicle Highway System. Greater potential cooperation with NIST is being sought.

As part of the Strategic Environmental Research and Development Program (SERDP), joint research is being conducted with the Environmental Protection Agency (EPA) and the Department of Energy (DOE) on many environmental problems. Each organization has a defined area of responsibility, thereby maximizing use of limited funds for addressing common DoD cleanup problems. A joint program under SERDP has also been initiated with EPA and DOE in development of a groundwater modeling system for contaminated site cleanup.

The Army, as lead agency for DoD, is working with EPA on biodiversity research through a biodiversity research consortium. Results of this cooperative effort will allow DoD to optimize its research in this area, thereby enhancing its capability to manage biodiversity on DoD sites in a bioregional and national context.

The Army cooperates on a smaller scale with a number of other government agencies to accomplish mutual goals by sharing unique capabilities. These agencies include the departments of Health and Human Services, Labor, and Education; the National Oceanic and Atmospheric Administration; the Food and Drug Administration; and the U.S. Geological Survey.

3 Army Efforts With Industry

Army technology can help produce a stronger civilian economy in partnership with industry, bringing new products and processes to the marketplace.

a *National Automotive Center*

The National Automotive Center (NAC), located at the Tank–automotive and Armaments Command (TACOM) in Warren, MI, is an integral part of TACOM's Tank–automotive RDEC (TARDEC). The NAC leverages commercial industry's large investment in automotive technology, research, and development and initiates shared technology programs that benefit military ground vehicle systems. The NAC is the Army's official link to industry, education, and government in developing important new dual-use automotive technologies that meet dual needs. The NAC identifies dual-use technologies that can benefit both defense and commercial industries, and then structures cooperative programs that deliver results through use of DUS&T initiatives, SBIR projects, CRDAs, and cooperative agreements and other non-FAR transactions as well as development contracts. The NAC is supported by the Automotive Research Center (ARC), a university-based U.S. Army center of excellence for advancing technology for high-fidelity simulation of military and civilian ground vehicles.

Several of NAC's key programs include:

- *21st Century Truck.* This initiative represents an extraordinary partnership among DoD, the Army, DOE, and DOT; the EPA; and the U.S. trucking industry. The purpose is to improve fuel efficiency, increase safety, reduce ownership and operating costs, reduce emissions, and enhance the performance of military and commercial trucks.

- *Commercially Based Tactical Truck (COMBATT).* The purpose is to adapt a modified commercial pickup truck to perform some of the missions now assigned to the HMMWV. This approach leverages commercial technologies and has potential to take advantage of high-volume commercial production lines, reduce overall design and development costs, and reduce cost of spares via commercial distribution.
- *Simulation Throughout the Life Cycle (SimTLC).* SimTLC is leveraging commercial technologies and developing the necessary interfaces and processes that allow the Army to acquire and support future systems and fielded system upgrades better, faster, and at a lower cost. SimTLC is developing managed, collaborative processes that fully exploit M&S throughout all phases of a system's life cycle.
- *Hybrid Electric Advanced Electric Wheel Drive Technology Program.* This is a joint project resulting from broad agency announcements (BAAs) the NAC used to seek proposals on fuel efficiency and alternative propulsion systems. The objective of the program is to evaluate the military application of this technology in a 20-ton gross vehicle weight mobility platform.
- *Fuel Cells.* The Army can leverage the technology developed by the private sector to reduce ground fleet fuel requirements. Fuel cells are one of the most promising technologies for meeting U.S. energy demands and military needs in the 21st century because they offer near-zero emission vehicles with long range, good performance, and rapid refueling.

b *National Rotorcraft Technology Center*

The National Rotorcraft Technology Center (NRTC), established in 1996, is a catalyst for facilitating collaborative rotorcraft R&D among the DoD (Army and Navy), NASA, the Federal Aviation Administration, industry, and academia. It serves as the means to cooperatively develop and implement a rotorcraft technology plan and national strategy that can effectively address both civil and military rotorcraft needs.

The NRTC includes industry and academia as partners in the Rotorcraft Industry Technology Association, a nonprofit corporation that focuses on developing rotorcraft design, engineering, and manufacturing technologies, and that shares technology among its members.

c *Institute for Creative Technologies*

The Institute for Creative Technologies (ICT) was established in 1999 as a union of the Army, the University of Southern California, and the entertainment industry. The ICT is aimed at providing soldiers with realistic training aids and tools that can be used in any setting and are entertaining enough to engage the soldier on the job and during his free time through compelling immersive environments and gaming concepts. Projects for FY01 are being discussed. The first three projects will develop subcomponents, such as artificially intelligent characters, future scenarios and 3D models for FCS, and a game engine that allows ubiquitous simulation. The last project, Vision Video, will be a compilation of technologies that demonstrates the type of training environment the ICT hopes to provide.

E INTERNATIONAL TECHNOLOGY LEVERAGING

The globalization of technology is an irreversible process that is radically changing the environment in which the Army trains, operates, and develops new systems and strategies. This, in turn, affects the Army's approach to developing its international technology leveraging strategy, which has become an increasingly important facet of technology development, given limited resources, new international threats, and international partners.

Globalization has also been viewed as a vulnerability for the United States, in that it can accelerate technology development for potential adversaries and increase U.S. dependence on international technology sources. By increasing U.S. influence with foreign nations and providing access to technological strengths residing outside the United States, however, globalization also provides many new possibilities to enhance U.S. policy options and defense capabilities.

1 Vision

International military–industrial–academic partnerships contribute to the warfighting capabilities of our soldiers and our allies by maintaining truly world-class technology and industrial bases built on a global-minded workforce and the best available industrial capabilities and services. Our international armaments cooperative strategy is a comprehensive effort to focus our diverse goals to:

- Maintain a global awareness of the best technological developments, and develop appropriate leveraging strategies.
- Arrange data and personnel exchanges, and participate in selected international forums to optimize the benefit to the U.S. Army.
- Develop senior-level guidance based on well-thought-out leveraging strategies.

2 Role of International Programs

Effective international cooperation demands both the development of sound, long-term partnerships and the ability to respond opportunistically when the occasion arises. Annex E in Volume II is designed to accomplish both these objectives. The annex provides insights into the broad capabilities of other countries that can be used to allocate resources to develop and cultivate cooperative programs with partners that are most likely to provide reliable long-term benefits. At the same time, identification of specific niches of excellence in research and application provides a basis for responding quickly to the changing political–military landscape while managing potential benefit to the Army S&T community. The annex also supports the development of international technology cooperation programs that promote interoperability among coalition partners and support peacetime engagement among allies. As a planning and reference tool, Annex E provides senior Army management with a roadmap for initiating discussions with partnering countries on technology cooperation.

As discussed in Annex E, identification of an opportunity for partnering establishes the existence of an acceptable technological quid pro quo. Within the guidelines of identified subtechnologies and countries, this annex provides an authoritative basis for the initiation of international agreements. However, the proponent organization must make the final determination that the specific quid pro quo exists for concluding cooperative agreements. This annex offers an annually updated snapshot in time, and new and rapidly emerging development may not be reflected. Because this document is publicly released, sensitive or classified information is not included.

3 Country Capabilities and Trends Analysis

Understanding trends is key to an effective strategy. Technology is advancing rapidly, and some opportunities may be time sensitive. Annex E contains a broad-based global technology and trends analysis.

Technology and research areas addressed herein are described in detail in Chapters III and IV. These areas span Army interests from research to advanced development. The areas have been identified as enabling the Army to upgrade currently fielded systems and to investigate new high-risk areas having significant potential in order to develop capabilities to support warfighters. Annex E closely follows the taxonomy of Chapters III and IV and is easily cross-referenced with the taxonomy of the DoD *Defense Technology Area Plan* and *Basic Research Plan.*

Analyses of technology and research capabilities span the globe. In all areas, commercial and government capabilities and programs are assessed. More than in previous years, multinational programs are identified as targets for U.S. cooperation in the various disciplines.

CRITERIA FOR DETERMINING COUNTRY CAPABILITIES/TRENDS

Comparative demonstrated technical performance—countries were examined for materials, components, or systems produced indigenously, relative to best U.S. practice

Indicators of recognized quality—the market share of commercial and defense products based on the research and technology areas in each nation was considered as part of the capability assessment

Strength and balance of supporting infrastructure—the number of R&D organizations, diversity of participation (industry, academia, and government), and level of investment were considered

Expert consensus—U.S. Army subject-matter experts reviewed the analyses

4 Global Technology and Research Capability Overview

Leadership in applied technology with identified military relevance is shared among relatively few countries (Figure VI–4)—the United States and its NATO allies, France, Germany, and the United Kingdom, and major non-NATO ally, Japan. Other countries identified as having significant capabilities include Israel, Canada, China, Russia, Italy, Sweden, Australia, and the Netherlands. In a number of countries, the trend is toward the development of more advanced capabilities. In most subareas, capability is widely disseminated, with three or more countries sharing world leadership. Even in those areas where the United States holds a unilateral lead, other countries provide significant technology leveraging opportunities in specific areas.

The number and geographic distribution of countries having significant S&T capabilities are large and can be expected to increase. In the global economy, reliable sources of electronics, computers, sensors, and new materials are becoming more widely available as advances spread rapidly throughout global markets. Computers and electronics are simply commodities—basic tools for studying the scientific areas that these countries have chosen, such as life sciences, biology, chemistry, and behavioral and medical sciences.

Annex E provides more detailed breakouts of specific technology development and basic research areas, respectively. Other countries are identified as having significant capabilities. The capabilities highlighted correlate to the areas where countries are shown in the individual subsection tables as having world-class capabilities and a level of activity that is expected to enhance or at least maintain their relative position.

LEVERAGING OPPORTUNITIES	BASIC RESEARCH	APPLIED RESEARCH
IN A MAJORITY OF ARMY S&T AREAS	**Germany** **France** **UK** **Japan** **Russia**	**France** **UK** **Germany** **Japan**
IN MANY ARMY S&T AREAS	**Israel** **Canada** **China** **Sweden** **Netherlands**	**Israel** **Russia** **Canada** **Sweden** **Netherlands** **Italy**
IN ONE OR MORE ARMY S&T AREAS	Australia Switzerland Italy Korea India Finland Poland Taiwan South Africa Austria Denmark Indonesia Brazil Czech Republic Spain Slovakia Singapore Belgium Cuba Hungary Turkey Argentina	Switzerland Korea China Australia Austria Singapore Poland India New Zealand South Africa Denmark Brazil Czech Republic Thailand Belgium Malaysia Kenya Norway

This rank ordering is based on the number of world-class leveraging opportunities across all research and technology areas of interest to the Army, as identified in Annex E, Volume II.

FIGURE VI–4. RANK ORDERING OF COUNTRY CAPABILITIES

GLOSSARY OF ABBREVIATIONS AND ACRONYMS AND INDEX

GLOSSARY

ABBREVIATIONS AND ACRONYMS

Symbols/Numbers

µm	micrometer
$/fh	dollars per flight-hour
$/hp	dollars per horsepower
2D	two dimensional
3D	three dimensional
4D	four dimensional

A

A/D	analog to digital
AAE	Army Acquisition Executive
A^2C^2S	Army Airborne Command and Control System
AAR	after action report
ABCS	Army Battle Command System
ABN	airborne
ABO	agent of biological origin
ACN	airborne communication node
ACSIM	Assistant Chief of Staff, Installation Management
ACT II	Advanced Concepts and Technology II
ACTD	Advanced Concept Technology Demonstration
ADC	analog-to-digital converter
ADD	automated DNA diagnostic [device]
ADKEM	Advanced Kinetic-Energy Missile
ADL	advanced distributed learning
ADS	Area Denial Systems
ADTT	Army Domestic Technology Transfer
AFSS	Advanced Fire Support System
AGES II	Air/Ground Engagement Simulation II
AGL	above ground level
AI	artificial intelligence
AIT	atmospheric interceptor technology
AJ	antijam
ALACV	Advanced Light Armament for Combat Vehicles
ALERT	Air/Land Enhanced Reconnaissance and Targeting
AMBL	Air Maneuver Battle Laboratory
AMC	Army Materiel Command
AMCOM	Aviation and Missile Command
AMD	air and missile defense
AMP	*Army Modernization Plan*
AMRDEC	Aviation–Missile Research, Development, and Engineering Center
AMTI	advanced munitions technology integration
AMUST	Airborne Manned/Unmanned System Technology
ANSR	Active No-Swashplate Rotor
ANSUR	anthropometric survey
ANVG	Advanced Night Vision Goggle
AoA	analysis of alternatives
APLA	antipersonnel landmine alternative
APOE	aerial port of embarkation
APS	Active Protection System; alternative propulsion sources
APT	advanced propulsion technology
ARAMS	Army Risk Assessment Modeling System
ARCAT	Advanced Rotorcraft Aeromechanics Technology
ARDEC	Armament Research, Development, and Engineering Center
ARI	Army Research Institute
ARL	Army Research Laboratory
ARO	Army Research Office
ARTS	Advanced Rotorcraft Targeting Systems
ASAS	All-Source Analysis System
ASB	Army Science Board
ASBREM	Armed Services Biomedical Research Evaluation and Management
ASE	aircraft survivability equipment
ASPO	Army Space Program Office
ASSH	aircraft system self-healing
ASTAMIDS	Airborne Standoff Minefield Detection System
ASTMIS	Army Science and Technology Management Information System
ASTMP	*Army Science and Technology Master Plan*
ASTWG	Army Science and Technology Working Group
ATACMS	Army Tactical Missile System
ATC	air traffic control
ATCCS	Army Tactical Command and Control System
ATCP	Army Transformation Campaign Plan
ATD	Advanced Technology Demonstration
ATDMP	Advanced Technology Demonstration Management Plan
ATEC	Army Test and Evaluation Command
ATGM	antitank guided missile
ATIRCM	Advanced Threat Infrared Countermeasures
ATM	asynchronous transfer mode
ATN	advanced tactical navigator
ATR	automatic target recognition
ATSP	active topical skin protectant
AWE	Army Warfighting Experiment

B

b	bit
B	byte

B/W	bandwidth
BAA	broad agency announcement
BAS	Battlefield Automated System
BAWS	Biological Aerosol Warning System
BC^2	battlespace command and control
BCBL	Battle Command Battle Laboratory
BCNS	behavioral, cognitive, and neural sciences
BCT	Brigade Combat Team
BCTP	Battle Command Training Program
BDA	battle damage assessment
BFM	battlescale forecast model
BioCOG	Biological Sciences Basic Research Coordination and Planning Group
BLOS	beyond line of sight
BMC^4I	battle management command, control, communications, computers, and intelligence
BMD	ballistic missile defense
BMDO	Ballistic Missile Defense Organization
Bn	battalion
BOA	battlefield ordnance awareness
bps	bits per second
BPV	battle planning and visualization
BRDF	bidirectional reflectance distribution function
BRP	*Basic Research Plan*
BSPS	Biological Sample Preparation System
BST	barium strontium titanate
BTN	battlespace tactical navigation
BW	biological warfare
BWA	biological warfare agent
BWI	Brilliant Weapons Integration

C

C	centigrade
C^2	command and control
C^2JISR	Command and Control for Joint Intelligence, Surveillance, and Reconnaissance
C^3	command, control, and communications
C^3I	command, control, communications, and intelligence
C^4	command, control, communications, and computers
C^4I	command, control, communications, computers, and intelligence
C^4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAA	Concept Analysis Agency
CAAM	computer-assisted artillery meteorological
CABS	Cockpit Airbag System
CAD	computer-aided design
CAFT	Center for Advanced Food Technology
CAGES	Command Air/Ground Electronic Combat Suite
CAM	computer-aided modeling
CAPS	Counteractive Protection System
CARC	chemical agent resistant coating
CARS	Contingency Airborne Reconnaissance System
CAT	Crew Integration and Automation Testbed
CATOX	catalytic oxidation
CATS	combined arms training strategy
CATT	combined arms tactical trainer
CAVE	computer-aided virtual environment
CB	chemical and biological
CBD	chemical and biological defense
CBDCOM	Chemical and Biological Defense Command
CBPS	chemical and biological protective shelter
CBTDEV	combat developer
CBW	chemical and biological warfare
CCA	close combat antiarmor
CCTT	Close Combat Tactical Trainer
CDA	commander's decision aid
CDAS	Cognitive Decision-Aiding System
CDC	Centers for Disease Control
CE	chemical energy
CECOM	Communications–Electronics Command
CEP	circular error probable; Concept Experimentation Program
CERL	Civil Engineering Research Laboratory
CFD	computational fluid dynamics
CGF	computer-generated forces
cGMP	current Good Manufacturing Practices
CHATH	chemically hardened, air-transportable hospital
CHPR	Cooper Harper Pilot's Rating
CHPS	Combat Hybrid Power System
CICM	communications integration and cosite mitigation
CID	combat identification
CIFER	comprehensive identification from frequency responses
CINC	commander in chief
CIS	chemical imaging sensor
CJCS	Chairman, Joint Chiefs of Staff
CKEM	Compact Kinetic-Energy Missile
CM	countermeasures
CMC	ceramic matrix composite
CMOS	complementary metal oxide semiconductor
CMTC	Combat Maneuver Training Center
CMWS	Common Missile Warning System
CO_2	carbon dioxide
COA	course of action
COAA	course-of-action analysis
COE	center of excellence
COMBATT	commercially based tactical truck
COMINT	communications intelligence
CONOPS	continuous operations
CONUS	continental United States
COP	common operational picture
COSSI	Commercial Operations and Support Savings Initiative
COTM	communication on-the-move
COTS	commercial off the shelf
CPAR	construction productivity advancement research
CRDA	cooperative research and development agreement

CRREL	Cold Regions Research and Engineering Laboratory
CSA	Chief of Staff of the Army
CSS	combat service support
CSSCS	Combat Service Support Control System
CTC	Combat Training Center
CVCA	combat vehicle concepts and analysis
CWA	chemical warfare agent

D

D&SABL	Depth and Simultaneous Attack Battle Laboratory
DARPA	Defense Advanced Research Projects Agency
DAS(R&T)	Department of the Army Secretary for Research and Technology
DASD(C^3)	Deputy Assistant Secretary of Defense for Command, Control, and Communications
dB	decibel
DBBL	Dismounted Battlespace Battle Laboratory
DBC	digital battlefield communications
DBS	Direct Broadcast Satellite
dc	direct current
DC2	Decontamination Solution 2
DCD	Director of Combat Development
DCSCD	Deputy Chief of Staff for Combat Developments
DCSDOC	Deputy Chief of Staff for Doctrine
DCSINT	Deputy Chief of Staff for Intelligence
DCSLOG	Deputy Chief of Staff for Logistics
DCSOPS	Deputy Chief of Staff for Operations
DCSPER	Deputy Chief of Staff for Personnel
DCSPRO	Deputy Chief of Staff for Programs
DDL	direct downlink
DDR&E	Director, Defense Research and Engineering
DEM	digital elevation model
DEPMEDS	deployable medical shelter
DET	dynamic environment and terrain
DEW	directed-energy weapon
DFL	direct fire lethality
DI&S	design integration and supportability
DIFM	distributive interactive fire mission
DIL	Digital Integration Laboratory
DIS	distributed interactive simulation
DISA	Defense Information Systems Agency
DISC^4	Director of Information Systems for Command, Control, Communications, and Computers
DISN	Distributed Interactive System Network
DMCD	directed missile countermeasures device
DNA	deoxyriborucleic acid
DOE	Department of Energy
DRAMA	Dynamic Readdressing and Management for Army 2010
DRB	Defense Review Board
DSB	Defense Science Board
DSCS	Defense Satellite Communications System
DTAP	*Defense Technology Area Plan*
DTLOMS	dcotrine, training, leader development, organizations, material, and soldiers
DTO	Defense Technology Objective
DTRA	Defense Threat Reduction Agency
DTSS	Digital Topographic Support System
DU	depleted uranium
DUS&T	Dual-Use Science and Technology
DUSA(IA)	Deputy Under Secretary of Defense for International Affairs
DUSA(OR)	Deputy Under Secretary of Defense for Operations Research
DUSD(AS&C)	Deputy Under Secretary of Defense for Advanced Systems and Concepts
DUSD(S&T)	Deputy Under Secretary of Defense for Science and Technology

E

EA	electronic attack
ECCM&C	engineering, combat construction, mobility, and countermobility
ECM	electronic countermeasures
ECOG	Electronics Coordinating Group
EEE	Eastern equine encephalitis
EFOGM	Enhanced Fiber-optic Guided Missile
EFP	explosively formed penetrator
EHF	extremely high frequency
ELF	extremely low frequency
ELINT	electronic intelligence
EM	electromagnetic
EMD	engineering and manufacturing development (now SDD)
EMI	electromagnetic interference
EMPRS	En Route Mission Planing and Rehearsal System
EO	electro-optic(al)
EOB	electronic order of battle
EP	area protect
EPA	Environmental Protection Agency
ERA	explosive reactive armor
ERDEC	Edgewood Research, Development, and Engineering Center
ES	electronic support
ESCOG	Environmental Sciences Coordinating Group
ESM	electronic support measure
ETC	electrothermal-chemical
ETEC	*Escherichia coli*
EV–II	Eagle Vision II
EW	electronic warfare
EWVA	electronic warfare vulnerability assessment
EXPLAN	execution plan

F

FAMSIM	family of simulations
FAR	Federal Acquisition Regulation
FBCB^2	Force XXI Century Battle Command Brigade and Below
FCR	fire control radar
FCS	Future Combat Systems
FCV	Future Combat Vehicle
FD	force development
FDA	Food and Drug Administration
FDD	First Digitized Division
FEA	finite element analysis
FedLab	Federated Laboratory
FFRDC	federally funded research and development center
FGM	functionally graded material
fh	flight-hour
FLIR	forward-looking infrared
FLOP	floating point operation
FLOT	forward line of own troops
FOC	future operational capability
FOCUS	Free-Space Optical Communication System
FOPEN	foliage penetration
FORSCOM	U.S. Army Forces Command
FOV	field of view
FPA	focal plane array
FSAP	full-spectrum active protection
FSATP	full'-spectrum threat protection
FSCS	Future Scout and Cavalry System
FSTP	full-spectrum threat protection
FTR	Future Transport Rotorcraft
FTTS	Future Tactical Truck System
FWTI	Future Warrior Technology Integration
FWV	fixed-wing vehicle

G

g	gravitational force; gram
G&C	guidance and control
GaAs	gallium arsenide
GaN	galium nitrogen
GAO	Government Accounting Office
GBS	ground-based sensor
GCCS	Global Command and Control System
GCSS–A	Global Combat Support System—Army
Ge	germanium
GFP	green fluorescent protein
GHz	gigahertz
GII	global information infrastructure
GIS	Geographic Information System
GloMo	global mobile
GPEN	ground penetration(ing)
GPRA	Government Performance and Research Act
GPS	Global Positioning System
GRP	glass-reinforced plastic
GSTAMIDS	Ground Standoff Mine Detection System
GVW	gross vehicle weight
GW	gross weight

H

HACT	Helicopter Active Control Technology
HBCU	historically black colleges and universities
HCF	high-cycle fatigue
HCTR	high-capacity trunk radio
HE	high explosive
HEAT	high-explosive antitank
HEL	high-energy laser
HF	high frequency
HFCS	HACT Flight Control System
HFRS	hantavirus fever with renal syndrome
HIV	human immunodeficiency virus
HLA	high-level architecture
HMD	head-mounted display
HMMWV	high-mobility, multipurpose wheeled vehicle
HPT	high-payoff target
HRED	Human Research Engineering Directorate
HR–GMTI	high-resolution—ground tracking target indication
HRW	high-resolution wind
HTI	horizontal technology integration
HTK	hit-to-kill
HTSC	high-temperature semiconductor
HV	hypervelocity

I

I/O	input/output
I^2	image intensification
IACOP	information assurance common operational picture
IBACS	Integrated Battlefield Area Communications System
IC	integrated circuit
ICH	improved cargo helicopter
ICM	integrated countermeasures
ICT	integrated concept team; Institute for Creative Technologies
ID&PE	information display and performance enhancement
IDM	Information Dissemination Management
IEW	intelligence and electronic warfare
IHPTET	Integrated High-Performance Turbine Engine Technology
IIT	integrated idea team
ILIR	in-house laboratory independent research
IMETS	Integrated Meteorological System
IMO	International Mathematical Olympiad
IMPRINT	integrated manpower and personnel integration
IMU	inertial measurement unit
INFOSEC	information security
InP	indium phosphide
INS	Inertial Navigation System
IOC	initial operational capability

IP	internet protocol
IPPD	integrated product and process development
IPR	in-process review
IR	infrared
IR&D	independent research and development
IRCM	infrared countermeasures
IREMBASS	Improved Romote Battlefield Sensor System
IRT	independent review team
IS	intelligent systems
ISAR	inverse synthetic aperture radar
ISAT	integrated situation awareness and targeting
ISDN	Integrated Services Digital Network
ISR	intelligence, surveillance, and reconnaissance
ISR&EW	intelligence, surveillance, and reconnaissance and electronic warfare
IVES	Intravehicular Electronics Suite
IWEDA	integrated weather effects decision aid

J

J	joule
JAC	joint area clearance
JAHUMS	Joint Advanced Health and Usage Monitoring System
JBPDS	Joint Biological Point Detection System
JBSDS	Joint Biological Standoff Detection System
JCBUD	Joint Chemical Biological Universal Detection
JCPE	Joint Collective Protection Equipment
JCSD	Joint Chemical Standoff Detector
JFOC	joint future operational capability
JIEC	Joint Integration and Evaluation Center
JISR	joint intelligence, surveillance, and reconnaissance
JPO	Joint Program Office
JPS	joint precision strike
JRTC	Joint Readiness Training Center
JSCBAWM	Joint Service Chemical Biological Agent Water Monitor
JSFXD	Joint Service Fixed Site Decontamination
JSGPM	Joint Service General-Purpose Mask
JSHS	Junior Science and Humanities Symposium
JSMCBD	Joint Service Modular Chemical Detection
JSSED	Joint Service Sensitive Equipment Decontamination
JSWAD	Joint Service-Wide Area Detection
JSWILD	Joint Service Chemical Warning and Identification LIDAR Dector
JTA	joint technical architecture
JTAGG	Joint Turbine Advanced Gas Generator
JTCOPS	Joint Transportable Collective Protection System
JTF	joint task force
JTR	Joint Transport Rotorcraft
JTRS	Joint Tactical Radio System
JVMF	joint variable message format
JWARN	Joint Warning and Reporting Network
JWCA	Joint Warfighting Capability Assessment
JWID	Joint Warrior Interoperability Demonstration
JWSTP	*Joint Warfighting Science and Technology Plan*

K

k	kilo
K	degree Kelvin
KAT	kill assessment technology
KE	kinetic energy
kg	kilogram
km	kilometer
kW	kilowatt
kWhr	kilowatt-hour

L

L/V	lethality and vulnerability
LADAR	laser radar
LAM	Loitering Attack Missile
LAM–A	Loitering Attack Missile for Aviation
LAMD	lightweight airborne multispectral minefield detection
LBR	laser beamrider (missile)
LCAR	low-cost active rotor
LCC	life-cycle cost
LCF	low-cycle engine
LCPK	low-cost precision kill
LED	light emitting diode
Li	lithium
LIDAR	light detection and ranging
LO	low observable
LOAL	lock-on after launch
Log C^2	logistics command and control
LOS	line of sight
LOSAT	line-of-sight antitank
LOTS	logistics-over-the-shore
LPD	low probability of detection
LPI	low probability of intercept
LRIP	low-rate initial production
LTL	less-than-lethal
LVOSS	Light Vehicle Obscurants Smoke System
LW	Land Warrior
LWIR	long-wavelength infrared
LWXXI	Land Warrior for the 21st century

M

m	meter; milli
M	mega
M&R	maintenance and repair
M&S	modeling and simulation
MACOM	major command
MANPADS	man-portable air defense
MANPRINT	manpower and personnel integration
ManTech	manufacturing technology
MATDEV	materiel developer
MAV	manned aerial vehicle
MBBL	Mounted Battlespace Battle Laboratory

Mbps	megabits per second
MCBD	medical chemical and biological defense
MCS	Maneuver Control System
MEADS	Medium-Extended Air Defense System
MECOG	Mechanics Coordinating Group
MEMS	microelectromechanical systems
MEP	mission equipment package
METSAT	meteorological satellite
MFG	master frequency generator
MFS^3	Multifunction Staring Sensor Suite
MGR	imaging ground radar
mh	man-hour
MH/K	mine hunter/killer
MHF	modernized Hellfire
MHz	megahertz
MI	minitority institution
MICOM	U.S. Army Missile Command
MILES	Multiple Integrated Laser Engagement System
MITL	man-in-the-loop
mm	millimeter
MMBL	Mounted Maneuver Battle Laboratory
MMC	metal matrix composite
MMIC	monolithic, microwave integrated circuit
MMR	multimission radar
MMS	meteorological measuring set
MMW	millimeter wave
MNS	mission needs statement
MOA	memorandum of agreement
ModHF/CM	Modernized Hellfire/Common Missile
ModSAF	Modular Semiautomated Force
MOSAIC	Multifunctional On-the-Move Secure, Adaptive, Integrated Communications
MOUT	military operations in urbanized terrain
MP–ERM	Multipurpose Extended-Range Munition
MPE	more powerful explosive
mph	miles per hour
MRC	military relevant chemical
MRMAAV	multirole, mission-adaptable air vehicle
MRMC	Medical Research and Materiel Command
ms	millisecond
MSBL	Maneuver Support Battle Laboratory
MSCM	multispectral countermeasures
MSE	mobile subscriber equipment
MSIP	multistage improvement program
MTBF	mean time between failure
MTI	moving target indicator
MTO	Manufacturing Technology Objective
MULE	Modular Unmanned Logistics Express
MURI	Multidisciplinary University Research Initiative
mWh	milliwatt-hour
MWIR	mid-wavelength infrared

N

NAC	National Automotive Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NCAR	National Center for Atmospheric Research
NCBR	nuclear, chemical, biological, and radiological
NCO	noncommissioned officer
NEDT	noise-equivalent delta temperature
NetFires	Networked Fires Weapon
NG	nitroglycerine
NGSM	next generation of scatterable munitions
NIST	National Institute of Standards and Technology
NLO	nonlinear optical
NLOS	non-line-of-sight
nm	nanometer
NMD	national missile defense
NOE	nap-of-the-Earth
NPOESS	National Polar Orbiting Environmental Satellite System
NPR	National Partnership for Reventing [Government]
NRTC	National Rotorcraft Technology Center
NSA	National Security Agency
NSC	Natick Soldier Center
NSF	National Science Foundation
NSTC	National Science and Technology Council
NTC	National Training Center

O

O&O	operational and organization
O&S	operations and support
OASA(ALT)	Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology
OASD	Office of the Assistant Secretary of Defense
OCSW	Objective Crew-Served Weapon
OE	optoelectronic
OEIC	optoelectronic integrated circuit
OFC	Objective Force capability
OFP	Objective Force Protection
OFTIW	Objective Force Targeting and Information Warfare
OICW	Objective Individual Combat Weapon
OneSAF	One Semiautomated Force
OOM	order of magnitude
OPAA	organophosphorus acid anhydrolasis
OPFOR	operational forces
OPH	organophosphorus hydrolasis
OPLAN	operational plan
OPNET	operational network
OPTEMPO	operational tempo
OR	operations research
ORD	operational requirements document
ORTA	Office of Research and Technology Applications
OSD	Office of the Secretary of Defense

OTM	on the move
OUSD	Office of the Under Secretary of Defense

P

P^3I	preplanned product improvement
PAA	phased-array antenna
PAC3	Patriot Advanced Capability 3
PAE	program analysis and evaluation
PAM	precision attack munition
PBG	photonic bandgap
PCS	personal communications system
P_d	probability of detection
PDRR	program development/risk reduction
PDT	passive dog tag
PEEK	polyetheretherketone
PEO	program executive officer
PERSTEMPO	personnel tempo
PGMM	Precision-Guided Mortar Munition
P_h	probability of hit
PIP	product improvement program
P_k	probability of kill
P.L.	public law
PLA	patent license agreement
PM	program manager
PNVG	Panoramic Night Vision Goggle
POL	petroleum, oil, and lubricants
POM	Program Objective Memorandum
POS/NAV	position and navigation
PP&T	personnel performance and training
PSA	pressure swing adsorption
PWB	printed wiring board

Q

QoS	quality of service

R

R&D	research and development
RACE	rotorcraft air combat enhancement
RAMM	Responsive Accurate Mission Module
RAP	radio access point
RCOE	Rotorcraft Center of Excellence
RDA	research, development, and acquisition
RDEC	research, development, and engineering center
RDS–21	Rotorcraft Drive Systems for the 21st Century
RDT&E	research, development, test, and evaluation
RDX	rapid detonating explosive
REAP	Research and Engineering Apprenticeship Program
REMBASS	Remotely Monitored Battlefield Sensor System
REST	Rotorcraft Enhanced Survivability Technologies
RF	radio frequency
RFCM	radio frequency countermeasures
RFPI	Rapid Force Projection Initiative
RHA	rolled homogenous armor
RISTA	reconnaissance, intelligence, surveillance, and target acquisition
RITA	Rotorcraft Industry Technology Association
RML	*Revolution in Military Logistics Campaign Plan—The Way Ahead*
RNA	ribonucleic acid
RNM	rotorcraft noise modeling
ROE	rules of engagement
RPA	rotorcraft pilot's associate
RPG	rocket-propelled grenade
RRAPDS	Remote Readiness Asset Prognostics/Diagnostics System
RSTA	reconnaissance, surveillance, and target acquisition
RTM	resin transfer molding
RTV	rapid terrain visualization
RUAV	rotorcraft unmanned aerial vehicle
RWST	Rotary-Wing Structures Technology
RWV	rotary-wing vehicle

S

s	second
S&T	science and technology
SA	small arms
SAM	surface-to-air missile
SAR	synthetic aperture radar
SARAP	Survivable, Affordable, Repairable Airframe Program
SAS	Situation Awareness System
SATCOM	satellite communications
SBCCOM	Soldier and Biological Chemical Command
SBIR	Small Business Innovation Research; Space-Based Infrared System
SCAPP	standardized camouflage paint pattern
SCF	specific fuel consumption
SDD	system development and demonstration (formerly EMD)
SDE	software development environment
SDR	surrogate digital radio
SDW	semirigid deployable wing
SEB	staphlococcal enterotoxin B
SELCOM	selection committee
SEM	science, engineering, and mathematics; standard electronic module
SEP	Soldier Enhancement Program
SERAT	structurally embedded reconfigurable antenna technology
SERDP	Strategic Environmental Research and Development Program
SERPACWA	skill exposure reduction paste against chemical warfare agent
SFREP	Summer Faculty Research and Engineering Program
SHF	super high frequency
SHORAD	short-range air defense
Shp	shaft horsepower
Si	silicon

SiC	silicon carbide
SIGINT	signals intelligence
SIL	system integration laboratory
SimTLC	simulation throughout the life cycle
SMART	Simulation Modeling for Acquisition, Requirements, and Training
SMDBL	Space and Missile Defense Battle Laboratory
SMDC	Space and Missile Defense Command
SOA	Special Operations aircraft
SOCOM	Special Operations Command
SOF	Special Operations Forces
SRA	Strategic Research Area
SRO	Strategic Research Objective
SSCN	Smart Sensor Communications Network
SSES	Suite of Survivability Enhancement Systems
SSHCL	Solid-State Heat Capacity Laser
SSL	solid-state laser
SSO	support and sustainment operations
STAS	short-term analysis service
STIRR	Subsystem Technology for Infrared Reductions
STO	Science and Technology Objective
STRICOM	Simulation, Training, and Instrumentation Command
STTR	Small Business Technology Transfer
SUO	small-unit operations
SWIR	short-wavelength infrared

T

T&D	transport and diffusion
T&E	test and evaluation
TACOM	Tank–automotive and Armaments Command
TARA	Technology Area Review and Assessment
TARDEC	Tank–automotive Research, Development, and Engineering Center
TCP	Transition Campaign Plan
TCP/IP	transmission control protocol/internet protocol
TD	technology demonstration
TDA	technology development approach
TEC	Topographical Engineering Center
TEG	tactical exploitation group
TERM	Tank Extended-Range Munition
TES	tactical engagement simulation; Tactical Exploration System
THAAD	theater high-altitude area defense
TI	Tactical Internet
TIC	toxic industrial/agricultural chemical
TIM	toxic industrial material
TIS	tactical input segment
TISR	tactical intelligence, surveillance, and reconnaissance
TM	tactical missile
TMD	theater missile defense
TMDE	test measurement and diagnostic equipment
TOC	tactical operations center
TOW	tube-launched, optically tracked, wire-guided missile
TP	thermo-plastic; turboprop
TPS	topical protective skin
TPV	thermophotovoltaic
TRADOC	Training and Doctrine Command
TRCS	Tactical Radio Communications System
TRL	technology readiness level
TS	turboshaft
TSA	temperature swing adsorption
TUV	tactical unmanned vehicle
TVP	thermophotovoltaic
TWT	traveling wave tube

U

UAV	unmanned aerial vehicle
UGV	unmanned ground vehicle
UHF	ultra high frequency
ULCANS–GP	Ultra-Lightweight Camouflage Net System—General Purpose
UMAST	universal, modular, adaptive SATCOM terminal
URI	University Research Initiative
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USSOCOM	U.S. Special Operations Command
UV	ultraviolet
UWB	ultra wideband
UXO	unexploded ordnance

V

V&V	verification and validation
VCSEL	vertical cavity surface emitting lasers
VE	virtual environment
VEE	Venezuelan equine encephalitis
VGARD	Variable Geometry Advanced Rotor Demonstration
VGART	Variable Geometry Advanced Rotor Technology
VHF	very high frequency
VIDS	Vehicular Integrated Defense System
VTC	videoteleconference
VTOL	vertical takeoff and landing

W

W	watt
WARSIM	warfighters' simulation
WCMNE	Wideband Communications Mobile Networking Environment
WEE	Western equine encephalitis
WES	Waterways Experiment Station
Wh	watt-hour
WIM	WARSIM Intelligence Module
WIN–T	Warfighter Information Network—Tactical
WLMP	Wholesale Logistics Management Program
WMD	weapons of mass destruction
WNR	wideband network radio
WP&S	warrior protection and sustainment

WPSM	warfighter physiological status monitoring
WRNT	Wideband Radio Network Testbed
WSMS	warrior systems modernization strategy
WTC	Warfighter/Technical Council

Index

A

Academic Leveraging, V–29

Acoustic, Magnetic, and Seismic Sensors, IV–98

ACTD
  See also Advanced Concept Technology Demonstrations
  process, I–18

Advanced Concept Technology Demonstrations, I–17, II–2, C–1, C–2
  Airbase/Port Biological Detection (Portal Shield) ACTD, III–86
  Hunter Standoff Killer Team ACTD, III–20
  Joint Continuous Strike Environment ACTD, C–12
  Joint Intelligence, Surveillance, and Reconnaissance ACTD, III–26, III–38, A–18, C–9
  Joint Medical Operations–Telemedicine ACTD, III–78, A–37, C–7
  Line-of-Sight Antitank ACTD, A–28, C–3
  Military Operations in Urbanized Terrain ACTD, III–62, A–33, C–5
  Rapid Terrain Visualization ACTD, III–25, III–106, A–40, C–10
  Theater Precision Strike Operations ACTD, A–11, C–4

Advanced Concept Technology Demonstrations—Proposed, Joint Area Clearance, III–106

Advanced Concepts, III–8

Advanced Concepts and Technology II Program, II–3

Advanced Technology Demonstrations, I–14, II–3, III–3, B–1
  See also Completed ATDs
  Advanced Night Vision Goggles ATD, III–15, A–7, B–14
  Agile Commander ATD, III–27, A–13, B–15
  Air/Land Enhanced Reconnaissance and Targeting ATD, III–15, A–3, B–4
  Crew Integration and Automation Testbed ATD, III–46, A–23, B–17
  Direct-Fire Lethality ATD, III–55, A–27, B–3
  Enhanced Coastal Trafficability and Sea State Mitigation ATD, III–104, III–112, A–43, B–10
  Future Scout and Cavalry System ATD, III–43, A–21, B–6
  Integrated Situation Awareness and Targeting ATD, III–14, III–37, A–4, B–13
  Logistics Command and Control ATD, III–26, III–113, A–44, B–12
  Low-Cost Precision Kill 2.75-Inch Guided Rocket ATD, III–16, III–55, A–7, B–9
  Multifunction Staring Sensor Suite ATD, III–36, III–47, III–98, A–22, B–5
  Multifunctional On-the-Move Secure Adaptive Integrated Communications ATD, III–27, A–14, B–16
  Multimission/Common Modular Unmanned Aerial Vehicle Sensors ATD, III–37, A–17, B–8
  Multirole Armament and Ammunition ATD, III–53, III–113, A–29, B–19
  Objective Crew-Served Weapon ATD, III–53, A–28, B–11
  Precision-Guided Mortar Munition ATD, III–56, A–27, B–2
  Robotic Follower ATD, III–48, A–25, B–18
  Tactical Command and Control Protect ATD, III–30, III–38, A–10, B–7

Advanced Technology Demonstrations—Proposed, Objective Force Warrior, III–60

Advanced Technology Development, III–1
  air and missile defense, III–97
  aviation, III–9
  biomedical, III–64
  chemical/biological defense, III–84
  command, control, communications, and computers, III–24
  engineering, combat construction, mobility, and countermobility, III–102
  ground combat and tactical systems, III–41
  intelligence, surveillance, and reconnaissance and electronic warfare, III–34
  logistics, III–109
  personnel performance, III–118
  Science and Technology Objectives, A–2
  soldier systems, III–58
  space, III–122
  strategy, III–3
  weapons, III–50

Aeromechanics, III–11, IV–6, E–7

Air and Missile Defense, III–97, IV–42
  information collection, III–98
  interceptors/seekers, III–99
  radar sensors, III–99
  roadmap, III–100

Antennas, III–30

Applied Analysis, V–32, E–86

Applied Research, IV–1
  aviation, IV–5
  battlespace environment, IV–108
  biomedical, IV–55
  biotechnology, IV–121
  chemical/biological defense, IV–64
  command, control, communications, and computers, IV–16
  electronic warfare, IV–24
  engineering, combat construction, mobility, and countermobility, IV–74
  ground combat and tactical systems, IV–28
  links to DTAP technology areas, IV–3
  links to Objective Force technology areas, IV–1
  logistics, IV–81
  materials, material processes, and structures, IV–88
  Science and Technology Objectives, A–50
  sensors and electronics, IV–95
  soldier and personnel technologies, IV–45
  strategy, IV–4
  weapons, IV–36

ARL Rodman Material Sciences Laboratory, F–8

ARL Zahl Physical Science Laboratory, F–9

Armor Materials by Design, V–26, D–12

Army Corps of Engineers, F–3

Army Domestic Technology Transfer Program, VI–4

Army Research Laboratory, F–6

Army S&T Organization, F–1

Army Science and Technology Strategy, I–1

Army Science Technology Working Group, II–4

Army Space and Missile Defense Command, F–6

Army Transformation, I–1

Army Vision, I–1

Artificial Intelligence, E–20

ATD. *See* Advanced Technology Demonstrations

Atmospheric Effects on Sensors and Systems, V–46, E–107

Atmospheric Sciences, V–45, E–106
- atmospheric effects on sensors and systems, V–46, E–107
- characterization of the atmospheric boundary layer at high resolution, V–46, E–108
- management of atmospheric information, V–46, E–108

Automatic Target Recognition, IV–98

Aviation, III–9, IV–5, E–7
- aeromechanics, III–11, IV–6, E–7
- flight control, III–12, IV–7, E–9
- fuels and lubricants, E–14
- objectives, IV–14
- propulsion, III–21, IV–12, E–13
- roadmap, III–23
- rotorcraft drives, III–21, IV–10, E–13
- Science and Technology Objectives, A–2, A–50
- structures, IV–9, E–9
- subsystems, IV–9, E–12
- subsystems and platform technologies, III–14

B

Ballistic Missile Defense Organization, VI–12

Basic Research, II–2, V–1
- dynamic nature, V–60
- future outlook, V–5
- goals, V–28
- impact of basic research areas on Army mission areas, V–59
- initiatives, V–5
- international, E–85
- responsibilities, V–2

Battlespace Environment, IV–108, E–82
- lower atmosphere environment, IV–112, E–84
- objectives, IV–120
- Science and Technology Objectives, A–117
- terrestrial environment, IV–109, E–83

Behavioral, Cognitive, and Neural Sciences, V–55, E–120
- leadership, V–56, E–121
- personnel, V–56, E–121
- soldier interface, V–57, E–123
- stress and cognitive processes, V–57, E–122
- training, V–56, E–121
- visual and auditory processes, V–56, E–122

Bio-Derived Electronic and Photonic Materials, IV–124

Bio-Derived Nanoceramics, IV–125

Biofouling and Biocorrosion, IV–125

Biological Sciences, V–53, E–114
- biomolecular and cellular materials and processes, V–53, E–115
- microbiology and biodegradation, V–54, E–119
- physiology, survivability, and performance, V–54, E–119

Biomedical, III–64, IV–55, E–57
- combat casualty care, III–76, IV–61, E–60
- infectious diseases of military importance, III–67, IV–57, E–58
- medical chemical and biological defense, III–70, IV–59
- medical chemical, radiological, and biological defense, E–59
- military operational medicine, III–73, IV–60, E–60
- objectives, IV–63
- roadmaps, III–78
- Science and Technology Objectives, A–35, A–83

Biomedical Research, V–50, E–110
- combat casualty care, V–52, E–113
- infectious diseases of military importance, V–51, E–111
- medical chemical and biological defense, V–51, E–111
- military operational medicine, V–51, E–113

Biomimetics, V–17, D–11

Biomolecular and Cellular Materials and Processes, V–53, E–115

Biopreservation of Food Rations, IV–126

Bioprocess Engineering, IV–124

Biosensors, IV–122

Biotechnology, IV–121
- bio-derived electronic and photomic materials, IV–124
- bio-derived nanoceramics, IV–125
- biofouling and biocorrosion, IV–125
- biopreservation of food rations, IV–126
- bioprocess engineering, IV–124
- biosensors, IV–122
- catalytic enzymes, IV–123
- low-observables materials, IV–122
- molecular recognition, IV–121
- molecular toxicology, IV–123
- objectives, IV–127

Broadband Communications, D–11

C

Catalytic Enzymes, IV–123

Centers of Excellence, V–5, VI–7

Characterization of the Atmospheric Boundary Layer at High Resolution, V–46, E–108

Chassis and Turret Structures, E–36

Chemical Detection, V–37, E–93

Chemical/Biological Defense, III–84, IV–64, E–61
- contamination avoidance, III–86, IV–65
- decontamination, III–89, IV–68, E–65
- detection, E–61
- modeling and simulation, IV–69, E–65
- objectives, IV–73
- protection, III–88, IV–67, E–64
- roadmaps, III–91
- Science and Technology Objectives, A–39
- smoke and obscurants, III–90, IV–71

Chemistry, V–37, E–93
- chemical detection, V–37, E–93
- demilitarization/environmental remediation, V–39, E–95
- energetic materials, V–38, E–95
- explosives and propellants, V–38, E–95
- power sources, V–38, E–93

Civil Engineering, IV–74

Civil Engineering and Environmental Quality, E–66

Coastal Hydraulics Laboratory, F–4

Cold Regions Research and Engineering Laboratory, F–3

Combat Casualty Care, III–76, IV–61, V–52, E–60, E–113

Combustion and Propulsion, V–44, E–105

Command and Control, III–25

Command, Control, and Communications, seamless communications, E–28

Command, Control, and Communications , E–26
  decisionmaking, E–29
  human–computer interface, E–27

Command, Control, Communications, and Computers, III–24, IV–16, E–15
  command and control, III–25
  command, control, and communications, E–26
  communications, III–27
  computers and software technology, E–17
  decisionmaking, IV–16
  modeling and simulation, E–30
  objectives, IV–22
  roadmap, III–33
  Science and Technology Objectives, A–10, A–53
  seamless communications, IV–18

Command, Control, Communications, Computers, and Intelligence, III–62, III–125

Commercial Operations and Support Savings Initiative, VI–5

Communications, III–27
  antennas, III–30
  information assurance, III–29
  mobile networking, III–27
  reachback, III–31
  secure personal communications, III–31
  unattended sensor networking, III–29

Compact Power, V–22, D–12

Completed Advanced Technology Demonstrations, III–4
  Battlespace Command and Control ATD, III–7
  Digital Battlefield Communications ATD, III–6
  Enhanced Fiber-Optic Guided Missile ATD, III–7
  Integrated Biodetection ATD, III–7
  Mine Hunter/Killer ATD, III–7
  Multispectral Countermeasures ATD, III–6
  Objective Individual Combat Weapon ATD, III–7
  Rotorcraft Pilot's Associate ATD, III–4

Composites Processing and Manufacturing, G–6

Computational Mathematics, V–32, E–86

Computer and Information Sciences, V–33, E–88
  formal methods for software engineering, V–34
  knowledge-based/database sciences, V–34, E–89
  natural language processing, V–35, E–89
  software engineering, E–88
  theoretical computer science, V–34, E–88

Computer Modeling and Simulation, F–16

Computers and Software Technology, E–17
  artificial intelligence, E–20
  high-performance computing and scalable systems, E–18
  networking, E–19
  software engineering, E–20

Congressionally Directed ManTech Programs
  Continuous Manufacturing Technology, G–6
  Munitions Manufacturing Technology, G–3
  Natural Gas, Engine-Drive Air Compressors, G–6
  Totally Integrated Munitions Enterprise, G–3

Construction Engineering Research Laboratory, F–3

Contamination Avoidance, III–86, IV–65

Countermobility, III–105

Current Battlespace Weather, IV–112

D

Decision Aids, IV–117

Decisionmaking, IV–16, E–29

Decontamination, III–89, IV–68, E–65

Defense Advanced Research Projects Agency, VI–10

Defense Science and Technology Reliance, VI–11

Defense Technology Objectives
  Airbase/Port Biological Detection (Portal Shield) ACTD, III–86
  Biological Sample Preparation System for Biological Identification, III–88
  Chemical Imaging Sensor, III–87
  Enzymatic Decontamination, IV–69
  Laser Standoff Chemical Detection Technology, III–86

Defense Threat Reduction Agency and Treaty Verification, VI–11

Demilitarization/Environmental Remediation, V–39, E–95

Denial Systems, III–38

Design Integration and Supportability, IV–47, E–54

Detection, E–61

Differences Between ATDs and ACTDs, C–2

Discrete Mathematics, V–33, E–88

DoD Acquisition Model, I–24

DoD University Research Initiatives, V–8

Dual-Use Science and Technology Program, VI–5

E

Early Entry and Resupply, III–111, IV–82

Edgewood Chemical Biological Center, F–7

Electro-Optic Sensors, IV–97

Electromagnetics, V–42, E–102

Electronic Area and Self-Protection, E–34

Electronic Attack/Area Protect, IV–24

Electronic Devices, E–79

Electronic Support, IV–26, E–34

Electronic Warfare, IV–24, E–33
  electronic area and self-protection, E–34
  electronic attack/area protect, IV–24
  electronic support, IV–26, E–34
  objectives, IV–27
  Science and Technology Objectives, A–58

Electronics, IV–99
  electronics materials, IV–104
  focal plane arrays, IV–103
  integrated platform electronics, IV–105
  microelectronics, IV–104
  millimeter-wave components, IV–100
  photonics, IV–101
  smart high-resolution displays, IV–100
  solid-state lasers, IV–102

Electronics Materials, IV–104

Electronics Processing and Manufacturing, G–7

Electronics Research, V–41, E–101
  electromagnetics, V–42, E–102
  information electronics, V–42, E–102
  solid-state and optical electronics, V–41, E–101

Energetic Materials, V–38, E–95

Energetics and Munitions, G–2

Engineering of Material Surfaces, E–100

Engineering, Combat Construction, and Countermine, E–66
  civil engineering and environmental quality, E–66
  mines and countermines, E–67

Engineering, Combat Construction, Mobility, and Countermobility, III–102, IV–74
  civil engineering, IV–74
  countermobility, III–105
  environmental quality, IV–76
  mobility, III–103
  mobility and countermobility, IV–77
  objectives, IV–79
  roadmap, III–107
  Science and Technology Objectives, A–40, A–95
  survivability, III–105
  sustainment engineering, III–106
  topographic engineering, III–106

Enhancing Soldier Performance, V–24, D–12

Environmental Laboratory, F–4

Environmental Quality, IV–76

Example International Research Facilities
  atmospheric sciences, E–109
  aviation, E–15
  behavioral, cognitive, and neural sciences, E–123
  biological sciences, E–120
  biomedical, E–61
  biomedical research, E–113
  chemical/biological defense, E–66
  chemistry, E–95
  command, control, communications, and computers, E–33
  computer and information sciences, E–90
  electronics research, E–102
  engineering, combat construction, and countermine, E–69
  ground combat and tactical systems , E–39
  materials science, E–100
  materials, material processes, and structures, E–74
  mathematical sciences, E–88
  mechanical sciences, E–106
  physics, E–92
  sensors and electronics, E–82
  soldier and human systems, E–57
  terrestrial sciences, E–110
  weapons, E–52

Explosives and Propellants, V–38, E–95

F

Facility Consolidation, F–7

Facility Modernization, F–8

Facility Upgrades, F–10

Federally Funded Research and Development Centers, VI–8

Federated Laboratory, V–13, F–10

Flight Control, III–12, IV–7, E–9

Fluid Dynamics, V–44, E–106

Focal Plane Arrays, IV–103

Formal Methods for Software Engineering, V–34

Fuels and Lubricants, E–14

Future Army Research Areas of Emphasis, V–16

Future Combat Systems, I-7, III-24, III-43, III-84, IV-83
  program, I–10
  Science and Technology Objective, A-24
  strategy, I–10
  technology areas, I–8

G

Geotechnical and Structures Laboratory, F–4

Global Science and Technology Watch, E–1

Ground Combat and Tactical Systems, III–41, IV–28, E–34
  chassis and turret structures, E–36
  integrated survivability, III–43, IV–30, E–36
  mobility, III–44, IV–32, E–37
  objectives, IV–35
  roadmap, III–49
  robotic vehicles, III–47
  robotics, IV–33
  Science and Technology Objectives , A–21, A–61
  systems integration, III–42, IV–29, E–35
  vehicle electronics, III–45, IV–33, E–38
  vehicle structures, IV–30

Guidance and Control, IV–37, E–41

Guns, III–53, IV–38, E–43

H

Hardware-in-the-Loop Simulation, F–19

High-Performance Computing and Scalable Systems, E–18

Historically Black Colleges and Universities and Minority Institutions, V–12, VI–8

Human–Computer Interface, E–27

I

Image Analysis, V–36, E–92

Imagery and Geospatial Research and Development Testbed, F–20

Impact of Basic Research Areas on Army Mission Areas, V–59

In-House Laboratory Independent Research, V–16

Independent Research and Development Program, VI–6

Individual/Land Warfare Training, III–120

Infectious Diseases of Military Importance, III–67, IV–57, V–51, E–58, E–113

Information Assurance, III–29

Information Collection, III–98
airborne collection systems, III–36
ground-based collection systems, III–36

Information Display and Performance Enhancement, IV–46, E–52

Information Electronics, V–42, E–102

Information Technology and Communications, F–21

Information Technology Laboratory, F–4

Infrastructure, F–1
facility consolidation, F–7
facility modernization, F–8
facility upgrades, F–10
physical facilities and equipment, F–3
ranges, F–11
shared facilities, F–10
specialized equipment, F–11

Institute for Creative Technologies, VI–15

Integrated Platform Electronics, IV–105

Integrated Sensory Science, V–35, E–90

Integrated Survivability, III–43, IV–30, E–36

Intelligence Processing and Fusion, III–37

Intelligence, Surveillance, and Reconnaissance and Electronic Warfare, III–34
denial systems, III–38
information collection
airborne collection systems, III–36
ground-based collection systems, III–36
intelligence processing and fusion, III–37
roadmap, III–40
Science and Technology Objectives, A–17

Intelligence, Surveillance, and Reconnaissance and Mapping, III–125

Intelligent Systems, V–21, D–11

Interceptors/Seekers, III–99

Interim Force, I–2

International Basic Research, E–85
atmospheric sciences, E–106
behavioral, cognitive, and neural sciences, E–120
biological sciences, E–114
biomedical research, E–110
chemistry, E–93
computer and information sciences, E–88
electronics research, E–101
materials science, E–96
mathematical sciences, E–86
mechanical sciences, E–102
physics, E–90
terrestrial sciences, E–109

International S&T Capabilities, E–1

International Technology Development, E–7
aviation, E–7
battlespace environment, E–83
biomedical, E–57
chemical/biological defense, E–61
command, control, communications, and computers, E–15
electronic warfare, E–33
engineering, combat construction, and countermine, E–66
ground combat and tactical systems, E–34
materials, material processes, and structures, E–69
sensors and electronics, E–74
soldier and human systems, E–52
weapons, E–39

International Technology Leveraging, VI–15

K

Knowledge-Based/Database Sciences, V–34, E–89

L

Leadership, V–56, E–121

Legacy Force, I–2

Lethality, III–59

Logistics, III–109, IV–81, D–1
applications of new SRO technologies, D–12
applications of SRA technologies, D–10
command and control—situational understanding, III–113, IV–83
CS/CSS transformation, III–109
demand reduction
power and energy, III–114, IV–85
prognostics, III–114, IV–84
resupply, III–112, IV–83
system reliability, III–113, IV–84
early entry and resupply, III–111, IV–82
objectives, IV–86
roadmap, III–115
Science and Technology Objectives, A–43, A–102
technology areas, D–5

Logistics Command and Control, situational understanding, III–113, IV–83

Logistics Demand Reduction
power and energy, III–114, IV–85
prognostics, III–114, IV–84
resupply, III–112, IV–83
system reliability, III–113, IV–84

Logistics Payoffs for Rapid Deployment and Reduced Sustainment, D–6

Low-Observables Materials, IV–122

Lower Atmosphere Environment, IV–112
current battlespace weather, IV–112
decision aids, IV–117
predicted battlespace weather, IV–114

Lower Atmosphere Environments, E–84

M

Management of Atmospheric Information, V–46, E–108

Manpower and Personnel Integration Program, III–8

ManTech
See also Manufacturing Technology
coding system, G–2

Manufacturing and Processing of Structural Materials, E–98

Manufacturing Demonstrations
Active Matrix Electroluminescent (AMEL) Displays, G–11
Active Matrix Liquid Crystal Displays, G–11
Advanced Filter Materials for High-Performance UV Sensors, G–10
Advanced Thin-Wall Casting Manufacturing Processes, G–5
Affordable Digital Signal Processing, G–10
Low-Cost Manufacturing Technology for Lightweight Electric Scanning Antenna, G–10
Seam-Sealing Technology Manufacturing Processes, G–7
Short-Wavelength Infrared-Gated Camera Tubes, G–11

Manufacturing Technology, E–74, G–1
objectives, G–13

Manufacturing Technology Objectives
Knowledge and Process Tools for Manufacturing of Affordable Composites, G–6
Large-Caliber Life Extension Via Tantalum Sputtering, G–4
Low-Cost Microelectromechanical Systems Inertial Measurement Units, G–9
Manufacturing Technology for Cooled and Uncooled IR Staring Sensors, G–8
Objective Individual Combat Weapon/Objective Crew-Served Weapon, G–2
Optics Manufacturing Technology, G–4
Uniform Cannon Tube Reshaping, G–5
Wafer-Applied Seal for Plastic Encapsulated Microcircuits Protection, G–9

Material Processes for Survivability, Life Extension, and Affordability, E–69

Material Synthesis/Self-Assembly, V–40

Materials, IV–89

Materials for Armor and Antiarmor, E–99

Materials Science, V–39, E–96
engineering of material surfaces, E–100
manufacturing and processing of structural materials, E–98
material synthesis/self-assembly, V–40
materials for armor and antiarmor, E–99
microscopic versus macroscopic domain, V–39
nondestructive characterization of components, E–100
processing of functional materials, E–99
smart materials, V–40

Materials, Material Processes, and Structures, IV–88, E–69
manufacturing technology, E–74
material processes for survivability, life extension, and affordability, E–69
materials, IV–89
objectives, IV–94
processes, IV–91
Science and Technology Objectives, A–107
structures, IV–92

Mathematical Sciences, V–31, E–86
applied analysis, V–32, E–86
computational mathematics, V–32, E–86
discrete mathematics, V–33, E–88
probability and statistics, V–32, E–86
systems and controls, V–32, E–87

Mechanical Sciences, V–43, E–102
combustion and propulsion, V–44, E–105
fluid dynamics, V–44, E–105
solid mechanics, V–43, E–104
structures and dynamics, V–43, E–104

Medical Chemical and Biological Defense, III–70, IV–59, V–51, E–111

Medical Chemical, Radiological, and Biological Defense, E–59

Medical R&D, VI–5

Metals Processing and Manufacturing, G–4

Microbiology and Biodegradation, V–54, E–119

Microelectronics, IV–104

Microminiature Multifunctional Sensors, V–25, D–12

Microscopic Versus Macroscopic Domain, V–39

Military Operational Medicine, III–73, IV–60, V–51, E–60, E–113

Millimeter-Wave Components, IV–100

Mines and Countermines, E–67

Missiles, III–54, IV–39, E–45

Mobile Networking, III–27

Mobile Wireless Communications, V–21

Mobility, III–44, III–60, III–103, IV–32, E–37

Mobility and Countermobility, IV–77

Modeling and Simulation, IV–69, E–30, E–65
simulation information, E–32
simulation interconntection, E–30
simulation interfaces, E–31
simulation representation, E–33

Modeling, Simulation, Software, and Testbeds, F–14

Molecular Recognition, IV–121

Molecular Toxicology, IV–123

N

Nanoscience, V–18, V–35, E–90

Nanotechnology, D–11

National Aeronautics and Space Administration, VI–13

National Automotive Center, VI–14

National Rotorcraft Technology Center, IV–13, VI–15

National Science Foundation, VI–7

Natural Language Processing, V–35, E–89

Networking, E–19

Nondestructive Characterization of Components, E–100

Nonlinear Optics and Nonlinear Dynamics, V–36, E–92

O

Objective Force, I–2
deployment timelines, D–2
task force, I–11
technology areas, I–6

Ordnance, III–55, IV–39, E–46

Outreach Programs, VI–9

P

Path to Transformation, I–4

Personnel, V–56, E–121, F–21

Personnel Performance, III–118
- individual/land warfare training, III–120
- roadmap, III–121
- Science and Technology Objectives, A–47
- simulation-enhanced training, III–120
- technology programs for improving personnel performance and leadership development, III–120
- unit collective training, III–119

Personnel Performance and Training, IV–50, E–55

Photonics, IV–101, V–36, E–92

Physical Simulation, F–19

Physics, V–35, E–90
- image analysis, V–36, E–92
- integrated sensory science, V–35, E–90
- nanoscience, V–35, E–90
- nonlinear optics and nonlinear dynamics, V–36, E–92
- photonics, V–36, E–92

Physiology, Survivability, and Performance, V–54, E–119

Power Sources, V–38, E–93

Predicted Battlespace Weather, IV–114

Probability and Statistics, V–32, E–86

Processes, IV–91

Processing of Functional Materials, E–99

Propulsion, III–21, IV–12, E–13

Protection, III–88, IV–67, E–64

R

R&D Resources, F–2

Radar Sensors, III–99, IV–96

Radio Frequency Directed-Energy Weapons, IV–41, E–51

Ranges, F–11

Rank Order of International S&T Capabilities, VI–18, E–4

Reachback, III–31

Resourcing the Army Strategy, I–22

Revolution in Military Logistics, D–1

Roadmaps
- air and missile defense, III–100
- aviation, III–23
- biomedical, III–78
- chemical/biological defense, III–91
- command, control, communications, and computers, III–33
- engineering, combat construction, mobility, and countermobility, III–107
- ground combat and tactical systems, III–49
- intelligence, surveillance, and reconnaissance and electronic warfare, III–40
- logistics, III–115
- personnel performance, III–121
- soldier systems, III–63
- space, III–127
- weapons, III–57

Robotic Vehicles, III–47

Robotics, IV–33

Rotorcraft Drives, III–21, IV–10, E–13

S

Science and Technology
- acquisition process, I–22
- planning and oversight, I–11
- process, I–13, I–16
- program characteristics, I–20
- strategy, I–1, I–4

Science and Technology Objectives, I–14, II–3, A–1
- 120-mm Extended-Range Mortar Cartridge, A–32
- A Multiantigen, Multistage *Plasmodium vivax* Malaria Vaccine, III–68, A–38
- A Multistage, Multiantigen *Plasmodium falciparum* Malaria Vaccine, III–68, A–83
- A Novel, Low-Cost, Composite Armor and Army Vehicle Materiel Manufacturing Process, A–107
- Advanced Acoustic/Seismic Systems, A–114
- Advanced Antennas, III–31, A–16
- Advanced Battlefield Processing Technology, A–54
- Advanced Bridging Virtual Prototyping Technology, IV–77, A–99
- Advanced Combat Identification Architecture, A–13
- Advanced Electronic Warfare Sensors, A–58
- Advanced Focal Plane Array Technology, A–109
- Advanced Geospatial Management for Information Integration and Dissemination, A–118
- Advanced Infrared Obscurants, III–90, A–39
- Advanced Light Armaments for Combat Vehicles, III–56, A–31
- Advanced Mine Detection Sensors, III–104, A–40
- Advanced Night Vision Goggles ATD, III–15, A–7, B–14
- Advanced Radar Deception and Countermeasures, A–59
- Advanced Rotorcraft Aeromechanics Technologies, IV–6, A–50
- Advanced Sensors for Smart Munitions, A–32
- Advanced Signature Management and Deception, A–110
- Advanced Tactical Engagement Simulations, A–79
- Advanced Tactical Fuels and Lubricants, III–114, IV–86, A–103
- Advanced Trauma Patient Simulation, III–78, IV–51, A–82
- Agile Commander ATD, III–27, A–13, B–15
- Agile Target Effect(s) Systems for the Battlefield, A–71
- Air/Land Enhanced Reconnaissance and Targeting ATD, III–15, A–3, B–4
- Airborne Manned/Unmanned System Technology Demonstration, III–19, A–6
- Airfields and Pavements To Support Force Projection, A–96
- Antennas for Communications Across the Spectrum, III–30, A–53
- Area Denial Systems, III–56, III–105, A–41
- Armament Decision Aids, IV–31, A–61
- Army Communications Integration and Cosite Mitigation, III–28, A–10
- Automatic Target Recognition for Weapons, IV–37, A–67
- Ballistic Protection for Future Combat Systems, IV–31, A–64
- Ballistic Protection for Improved Individual Survivability, A–76
- Battlefield Ordnance Awareness, III–113, III–126, A–48
- Battlespace Tactical Navigation, III–26, A–12
- Blood Products, III–76, A–93
- Buried Unexploded Ordnance, A–99
- Cannon Wear and Erosion, A–107
- Cognitive Engineering of the Digital Battlefield, A–75

Collaboration Technology for the Warfighter, A–55
Combat Hybrid Power Systems, III–45, IV–32, A–62
Combat Rations for Enhanced Warfighter Logistics, III–62, III–112, A–45
Combat Vehicle Concepts and Analysis, IV–29, A–62
Common Diagnostic Systems for Biological Threats and Endemic Infectious Diseases, III–69, III–70, A–37
Compact Kinetic-Energy Missile Technology, IV–38, A–68
Compact Laser Sources for Infrared Countermeasures, A–60
Computer-Generated Forces, A–75
Concepts for 21st Century Truck-Based Tactical Vehicles, III–113, A–63
Conducting Nanocomposites and Nanofibers for Warrior Systems, A–80
Counteractive Protection Systems Third-Generation Radio Frequency Countermeasures, III–55, A–30
Crew Integration and Automation Testbed ATD, III–46, A–23, B–17
Deep Throttling Booster, A–71
Deep-Attack and Indirect-Fire Meteorological Improvement, A–120
Development of a New Standard Military Insect Repellent, III–70, A–91
Direct-Fire Lethality ATD, III–55, A–27, B–3
Dismounted Warrior Command, Control, Communications, Computers, and Intelligence Technologies, A–55
Drug To Treat Multidrug-Resistant and Severe and Complicated Malaria, III–68, A–35
Dynamic Readdressing and Management for Army 2010, IV–20, A–56
Electromagnetic Gun Technology, A–72
Enhanced Coastal Trafficability and Sea State Mitigation ATD, III–104, III–112, A–43, B–10
Environmental Cleanup, A–98
False Alarm Reduction for Improved Operational Tempo, III–104, A–42
Field Medical Monitoring and Therapeutic Devices for Casualty Care, III–77, A–38
Flexible Sustainer for Multimission Weapons, A–66
Force Protection Against Terrorist Threats, A–97
Force Protection on the Battlefield, A–96
Free-Space Optical Communication System, IV–20, A–57
Full-Spectrum Active Protection, III–43, A–23
Fusion of Warfighter Performance, Environmental, and Physiologic Models, III–74, A–86
Future Combat Systems, III–43, A–24
Future Combat Systems Mine Detection and Neutralization, III–104, IV–78, A–100
Future Scout and Cavalry System ATD, III–43, A–21, B–6
Future Warrior Technology Integration, A–34
Ground Propulsion and Mobility, III–45, A–21
Head-Supported Mass: Warfighter Health and Performance, III–76, A–92
Helicopter Active Control Technology, III–12, A–2
Hemorrhage Control, III–76, A–93
High-Energy, Cost-Effective Primary and Rechargeable Batteries, III–114, IV–85, A–102
Inhalation Injury and Toxicology Models, A–90
Injury Prevention and Restraint Technologies for Ground Vehicles and Helicopters, III–76, A–89
Innovative Strategies To Assess Health Risks From Environmental Exposure to Toxic Chemicals, III–74, A–89
Integrated Countermeasures, III–15, III–39, III–44, A–5
Integrated High-Performance Turbine Engine Technology Joint Turbine, III–22, A–5
Integrated Power Generation and Management Technologies, III–115, IV–85, A–102
Integrated Sensor Modeling and Simulation, A–110
Integrated Situation Awareness and Targeting ATD, III–14, III–37, A–4, B–13
Intervehicle Embedded Simulation Technology, A–74
Joint Intelligence, Surveillance, and Reconnaissance ACTD, III–26, III–38, A–18, C–9
Joint Medical Operations–Telemedicine ACTD, III–78, A–37, C–7
Laser Bioeffects and Treatment, III–75, A–84
Laser Protection for Ground Vehicle Vision Systems, IV–31, A–61
Light Fighter Lethality, A–72
Lightweight Airborne Multispectral Minefield Detection, III–104, A–41
Lightweight Soldier, A–77
Line-of-Sight Antitank ACTD, A–28, C–3
Lines of Communication Assessment and Repair, A–97
Load Carriage Optimization for Enhanced Warfighter Performance, A–77
Logistics Command and Control ATD, III–26, III–113, A–44, B–12
Loitering Attack Munition–Aviation, III–17, A–70
Low-Cost Active Rotor, IV–7, A–52
Low-Cost Precision Kill 2.75-Inch Guided Rocket ATD, III–16, III–55, A–7, B–9
Low-Cost, Electro-Optic/Infrared Countermeasures, A–58
Low-Cost, Electronically Scanned Antenna, A–111
Low-Power Display Components, A–113
Low-Power, Uncooled Infrared Sensor, A–33
Medical Countermeasures for Filoviridae, III–71, A–35
Medical Countermeasures for Orthopox Viruses, III–72, A–36
Metal Matrix Composites for Ordnance Applications, A–108
Micro-Eyesafe, Solid-State Laser Sources, A–111
Microelectromechanical Systems-Based Angular Rate Sensors, A–70
Military Operations in Urbanized Terrain ACTD, III–62, A–33, C–5
Modernized Hellfire/Common Missile, III–16, III–55, A–6
Multiagent Vaccines for Biological Threat Agents, III–73, A–36
Multifunction Radio Frequency Sensor Technology, A–115
Multifunction Staring Sensor Suite ATD, III–36, III–47, III–98, A–22, B–5
Multifunctional Fabric System, A–74
Multifunctional On-the-Move Secure Adaptive Integrated Communications ATD, III–27, A–14, B–16
Multimission Radar, III–36, III–99, A–19
Multimission/Common Modular Unmanned Aerial Vehicle Sensors ATD, III–37, A–17, B–8
Multirole Armament and Ammunition ATD, III–53, III–113, A–29, B–19
Munitions Production Compliance Technology, A–95
Near-Infrared Sensors, A–109
New Assessment Techniques to Maximize 21st Century Noncommissioned Officer Performance, A–78
Nucleic Acid (DNA-Based) Vaccines To Prevent Dengue, III–69, A–91
Objective Crew-Served Weapon ATD, III–53, A–28, B–11
Objective Individual Combat Weapon System Enhancements, III–54, A–30
Obstacle Marking and Vehicle Guidance, IV–77, A–100
On-the-Move Tactical Satellite Communications Technology, III–32, A–12
Optimal Parameters for the Battlefield Resuscitation of Combat Casualties, III–76, A–92
Optimization of Physical Performance, III–73, A–84
Optimization of Physical Performance With Optical and Electro-Optical Systems and Materials, III–74, A–85
Overhead Sensor Technology for Battlefield Characterization, III–98, III–126, A–48
Performance Enhancement and Injury Prevention in Hot Environments, III–74, A–87
Personal Communications System for the Soldier, A–54

Petroleum, Oil, and Lubricants Quality Analyzer and Sensors, III–114, A–104
Pharmacological Strategies To Enhance Mental Performance in Fatigued Soldiers, III–73, A–88
Point-Hit Multiple Launch Rocket System, A–69
Power Conversion Technology for Future Combat Systems, III–115, A–105
Precision Roll-On/Roll-Off Air Delivery, III–61, III–112, A–45
Precision-Guided Mortar Munition ATD, III–56, A–27, B–2
Prevention of Diarrheal Diseases, III–68, A–86
Profiler Data Fusion, A–119
Quick Look, A–17
Rapid Analysis of Food and Water for Chemical and Microbial Contaminants, III–112, A–85
Rapid Generation of a Common Synthetic Battlespace for Strike Force, A–121
Rapid Mapping Technology, A–118
Rapid Terrain Visualization ACTD, III–25, III–106, A–40, C–10
Reforming Diesel (Cogeneration), III–62, III–115, A–43
Remote Readiness Asset Prognostics/Diagnostics System, IV–85, A–105
Responsive Accurate Munition Module, III–54, A–31
Robotic Follower ATD, III–48, A–25, B–18
Rotary-Wing Structures Technology, III–14, A–3
Rotorcraft Drive Systems for the 21st Century, III–21, A–8
Rotorcraft Enhanced Survivability Technologies, IV–10, A–51
Rotorcraft Open Systems Avionics, A–51
Semiautonomous Robotics for Future Combat Systems, IV–34, IV–82, A–64
Sensor Optoelectronic Processing, A–115
Sensors for the Objective Force, A–20
Signature Management for Future Combat Systems, III–43, III–105, A–25
Simulation-Based Aviator Training, A–78
Smart Sensor Communication Networks, III–29, A–15
Solid-State Heat Capacity Laser, IV–42, A–73
Space Surveillance, III–126, A–49
Spectral/Spatial Data Exploitation for Terrain Categorization and Target Identification, A–116
Survivability Technology Integration Program, III–44, A–26
Sustainable Military Use and Stewardship of Army Lands, A–95
Tactical Command and Control Protect ATD, III–30, III–38, A–10, B–7
Tank Extended-Range Munition, III–56, A–29
Target Destruct, III–56, A–66
Theater Precision Strike Operations ACTD, A–11, C–4
Third-Generation Infrared Imaging Technology, A–112
Three-Dimensional Dynamic Multispectral Synthetic Scene Visualization, A–119
Training Strategies for the Objective Force, III–119, A–47
Training Tools for Collaborative Web-Based Environments, IV–51, A–81
Variable-Geometry Advanced Rotor Technology, IV–6, A–50
Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal, A–79
Warfighter Electronic Collection and Mapping, III–36, A–18
Warfighter Physiological Status Monitoring, A–83
Warrior Extended Battlespace Sensors, A–113
Warrior Systems Modeling Technology, A–81
Water Purification Technology, III–112, A–104
Weather Effects and Battlescale Forecasts for Combat Simulation and Training, A–117
Weather Impacts and Decision Aids for Mission Rehearsal, Training, and Battlefield Execution, A–117
Wide-Span Airbeam Shelter for Logistics Applications, A–44

Scientific Research Areas, V–31
  atmospheric sciences, V–45
  behavioral, cognitive, and neural sciences, V–55
  biological sciences, V–53
  biomedical research, V–50
  chemistry, V–37
  computer and information sciences, V–33
  electronics research, V–41
  materials sciences, V–39
  mathematical sciences, V–31
  mechanical sciences, V–43
  physics, V–35
  terrestrial sciences, V–48

Scientific Services Program, VI–12

Seamless Communications, IV–18, E–28

Secure Personal Communications, III–31

Sensors, IV–96, E–74
  acoustic, magnetic, and seismic sensors, IV–98
  automatic target recognition, IV–98
  electro-optic sensors, IV–97
  radar sensors, IV–96

Sensors and Electronics, IV–95, E–74
  electronic devices, E–79
  electronics, IV–99
  objectives, IV–106
  Science and Technology Objectives, A–109
  sensors, IV–96, E–74

Shared Facilities, F–10

Signature Physics and Fusion, IV–110

Simulation Information, E–32

Simulation Interconnection, E–30

Simulation Interfaces, E–31

Simulation Representation, E–33

Simulation, Training, and Instrumentation Command, F–4

Simulation-Enhanced Training, III–120

Single-Investigator Programs, V–13

Small Business Innovation Research Program, II–4, VI–2

Small Business Technology Transfer Program, VI–3

Smart High-Resolution Displays, IV–100

Smart Materials, V–40

Smart Materials and Structures, V–19

Smart Structures, D–11

Smoke and Obscurants, III–90, IV–71

Software Engineering, E–20, E–88

Software Technology, F–18

Soldier and Human Systems, E–52
  design integration and supportability, E–54
  information display and performance enhancement, E–52
  personnel performance and training, E–55
  survivability and performance enhancement, E–55

Soldier and Personnel Technologies, IV–45
  design integration and supportability, IV–47
  information display and performance enhancement, IV–46
  objectives, IV–53
  personnel performance and training, IV–50
  Science and Technology Objectives, A–74
  warrior protection and sustainment, IV–48

Soldier Interface, V–57, E–123

Soldier Systems, III–58
command, control, communications, computers, and intelligence, III–62
lethality, III–59
mobility, III–60
roadmap, III–63
Science and Technology Objectives, A–33
survivability, III–59
sustainability, III–61

Solid Mechanics, V–43, E–104

Solid-State and Optical Electronics, V–41, E–101

Solid-State Lasers, IV–102

Space, III–122
command, control, communications, computers, and intelligence, III–125
intelligence, surveillance, and reconnaissance and mapping, III–125
roadmap, III–127
Science and Technology Objectives, A–48
space control, III–126

Space Control, III–126

Specialized Equipment, F–11

STO. *See* Science and Technology Objectives

STO/DTO Mapping, A–123

Strategic Research Areas, D–9
biomimetics, D–11
broadband communications, D–11
compact power, D–12
intelligent systems, D–11
nanotechnology, D–11
smart structures, D–11

Strategic Research Objectives, I–20, II–2, V–17, D–12
armor materials by design, V–26, D–12
biomimetics, V–17
compact power, V–22
enhancing soldier performance, V–24, D–12
intelligent systems, V–21
microminiature multifunctional sensors, V–25, D–12
mobile wireless communications, V–21
nanoscience, V–18
smart materials and structures, V–19

Stress and Cognitive Processes, V–57, E–122

Structures, IV–9, IV–92, E–9

Structures and Dynamics, V–43, E–104

Subsystems, IV–9, E–12

Subsystems and Platform Technologies, III–14

Survivability, III–59, III–105

Survivability and Performance Enhancement, E–55

Sustainability, III–61

Sustainment Engineering, III–106

Synthetic Training, F–14

Systems and Controls, V–32, E–87

Systems Integration, III–42, IV–29, E–35

T

Technology Demonstrations
Active No-Swashplate Rotor, III–12
Active Topical Skin Protectant, III–71
Advanced Adsorbents for Protection Applications, III–89
Advanced Antimalarial Drugs, III–68
Advanced Diagnostics, III–70
Advanced Electronic Warfare Sensors, III–37
Advanced Master Frequency Generator Effort, III–100
Advanced Munitions Technology Integration, III–19
Advanced Rotorcraft Targeting Systems, III–15
Advanced Windows Technology Effort, III–100
Aerospace Control, III–127
Affordable Precision Airdrop Resupply, III–112
Army.com, III–29
Atmospheric Interceptor Technology Program, III–99
Battle Management Command, Control, Communications, Computers, and Intelligence, III–127
Battlefield Management/Joint Warning and Reporting Network P3I, III–87
Brilliant Weapons Integration, III–17
Chemical Agent Prophylaxis Stage II, III–71
Collaboration Technology for the Warfighter, III–26
Combat Vehicle Mobility Technology, IV–32
Combined Malaria Vaccine, III–68
Common Air/Ground Electronic Combat Suite, III–19, III–37
Counter Intelligence, Surveillance, and Reconnaissance, III–39
Covert Nap-of-the-Earth Flight, III–18
Demonstration III Experimental Unmanned Vehicle, III–47
Dental Disease Reduction, III–78
Deployment Stress Models and Countermeasures, III–74
Digital Topographic Support System, III–106
Dismounted Warrior Command, Control, Communications, Computers, and Intelligence Technologies, III–31
Distant Smoke, III–90
Drug for Prevention of Resistant Malaria, III–68
E–Sustainment, III–26, III–112
Eagle Vision II, III–125
Fourth-Generation Cockpit, III–18
Full-Spectrum Aviation Threat Protection, III–17
Future Transport Rotorcraft 15,000-hp Class Engine Demonstrator, III–22
Hantavirus Vaccines, III–69
Human Immunodeficiency Virus (HIV–1) Vaccine, III–69
Image Intensification/Forward-Looking Infrared Fusion Pilotage, III–16
Insect Vector Controls, III–70
Joint Service Chemical Biological Agent Water Monitor, III–87
Joint Service Chemical Ensemble, III–88
Joint Service Collective Protection, III–89
Joint Service Modular Chemical Biological Detection, III–87
Joint Service Sensitive Equipment Decontamination, III–89
Joint Service-Wide Area Detection, III–87
Kill Assessment Technology, III–99
Liquid Surface Detection, III–88
Low-Level Toxicology, III–88
Medical Countermeasures Against Vesicants Stage II, III–71
Medical Countermeasures for Brucellosis, III–71
Medical Countermeasures for Encephalitis Viruses, III–71
Medical Countermeasures for Ricin, III–72
Medical Countermeasures for Staphylococcal Enterotoxins, III–72

Medical Countermeasures for *Yersinia pestis*, III–71
Medical Modeling and Informatics, III–78
Meningococcal Vaccine, III–69
Military Health Behaviors Promotion/Interventions, III–73
Millimeter-Wave Screening, III–90
Modular Unmanned Logistics Express, III–20, III–112
More Electric Rotorcraft, III–13
Multimode, Multiband Unmanned Aerial Vehicle Synthetic Aperture Radar, Moving Target Indicator, and Foliage Penetration Radar, III–37
Multirole Mission Adaptable Air Vehicle, III–20
Multispectral Smoke Pot, III–90
Network Emitter Targeting and Attack, III–38
Network Management Assistant (E–Assistant), III–28
Neuroprotection, III–78
Next-Generation Satellite Communications, III–32
Objective Force Logistics Technology, III–112
Objective Force Protection, III–39
Objective Force Targeting and Information Warfare, III–39
Objective Individual Combat Weapon (OICW) System Enhancements, III–54
Oral Multidisease, Antidiarrheal Vaccine, III–69
Owning the Weather, III–38
Radio Frequency Target Discrimination and Recognition, III–100
Rotary-Wing Vehicle Attack/Scout Mission Equipment Package Integration, III–20
Rotary-Wing Vehicle Prognostics, III–114
Second-Generation Robotic, III–48
Small Engine Program, III–22
Small Rotorcraft Drive Technology, III–21
Small-Unit Unmanned Aerial Vehicle Synthetic Aperture Radar, III–37
Strapdown Seeker Effort, III–99
Superior Decontamination System, III–90
Tactical Information Assurance Technology, III–30
Third-Generation Mission Equipment Package Sensor Integration, III–20
Universal Handset, III–31
Variable Geometry Advanced Rotor Demonstration, III–11
Warrior/Platform Command and Control, III–26
Wheeled Vehicle Mobility, III–45
Whole Body Blast Bioeffects/Blunt Trauma Injury Models, III–75

Technology Development, IV–1
See also Applied Research
international, E–7
Science and Technology Objectives, A–50

Technology Development and Transition, III–3

Technology Programs for Improving Personnel Performance and Leadership Development, III–120

Technology Readiness Levels, I–21, A–122

Technology Transfer, VI–1
medical R&D, VI–5

Technology Transition, III–1
See also Advanced Technology Development
Science and Technology Objectives, A–2

Terrain Properties and Characterization, V–48, E–110

Terrestrial Environment, IV–109, E–83
signature physics and fusion, IV–110
topography, IV–111

Terrestrial Processes and Landscape Dynamics, V–48, E–111

Terrestrial Sciences, V–48, E–109
terrain properties and characterization, V–48, E–110
terrestrial processes and landscape dynamics, V–48, E–110
terrestrial system modeling and model integration, V–49, E–110

Terrestrial System Modeling and Model Integration, V–49, E–111

Test and Evaluation Simulation, F–20

Theoretical Computer Science, V–34, E–88

Topographic Engineering, III–106

Topographic Engineering Center, F–3

Topography, IV–111

Training, V–56, E–121

Training and Doctrine Command, II–1
activities, II–2
role in S&T, II–1
warfighting experimentation, II–2

Transformation Strategy, I–1

U

U.S. Special Operations Command, VI–12

Unattended Sensor Networking, III–29

Unit Collective Training, III–119

University Research Initiative, VI–7

V

Vehicle Electronics, III–45, IV–33, E–38

Vehicle Structures, IV–30

Visual and Auditory Processes, V–56, E–122

W

Warfighter/Technical Council, II–4

Warfighting Experimentation, II–2

Warfighting Rapid Acquisition Program, II–3

Warrior Protection and Sustainment, IV–48

Weapons, III–50, IV–36, E–39
air and missile defense, IV–42
guidance and control, IV–37, E–41
guns, III–53, IV–38, E–43
missiles, III–54, IV–39, E–45
objectives, IV–43
ordnance, III–55, IV–39, E–46
radio frequency directed-energy weapons, IV–41, E–51
roadmap, III–57
Science and Technology Objectives, A–27, A–66
weapons lethality and vulnerability, IV–40, E–50

Weapons Lethality and Vulnerability, IV–40, E–50

Women in Science and Engineering, VI–9

Y

Youth Science Activities, VI–9